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THINNING AS A MEANS OF CORRECTING BIENNIAL BEARING IN APPLES[1]

D. V. Fisher[2] and J. E. Britton[3]

Dominion Experimental Station, Summerland, B.C.

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INTRODUCTION

Wherever apples are grown biennial bearing is a problem. Biennial bearing is influenced to a large degree by variety and methods of orchard management, but under extreme circumstances even the most regular bearing varieties and best cared for orchards may lapse into an alternate bearing condition. With varieties in which small sized apples are desired, fruit size in the "off" year crop of biennial bearing trees may be so large that the apples cannot be marketed at a profit to the grower. On the other hand, when large fruited varieties such as Delicious and Rome Beauty lapse from their annual bearing habit into the biennial bearing condition, the fruit in the "on" year may be too small to bring the best return. Moreover, in all varieties the characteristic large sized apples produced by biennial bearing trees in their "off" year are often misshapen and poorly coloured and have a reduced storage life owing to early development of storage disorders. The results of biennial bearing therefore influence different varieties in different ways, and whether or not it is desirable to bring about a condition of annual bearing in all varieties is an open question.

REVIEW OF LITERATURE

Biennial bearing in apples has received the attention of a number of investigators. The nutritional aspects of the problem have been investigated by Hooker (7), Potter *et al.* (13, 14, 16), and Murneek (12) among others. These workers emphasize the fact that differentiation of fruit buds is related to the presence of surplus supplies of carbohydrates and nitrogen in excess of the amounts demanded by the spurs for nutrition of the fruits and development of new wood growth. While a certain degree of balance between carbohydrates and nitrogen is essential for flower bud differentiation, nevertheless certain minimum reserves of these substances must be present in the spurs. Most investigations reveal that failure of fruit trees to form fruit buds in the heavy bearing year is related to an acute deficiency of mobile nitrogen reserves in the spurs at the time of flower differentiation. This is occasioned by the heavy demand placed

[1] Contribution No. 569 from the Division of Horticulture, Experimental Farms Service, Dominion Department of Agriculture, Ottawa, Canada.
[2] Graduate Assistant.
[3] Assistant Superintendent.

upon the spurs for nitrogen required for the development of the heavy set of fruit. Under other circumstances it is conceivable that fruit bud formation might suffer from carbohydrate deficiency.

The practical approach to modification of biennial bearing has been mainly through fertilization, pruning, and fruit thinning. Roberts (17) suggests that use of readily available nitrogen in the orchard very early in the spring may reduce the tendency of trees to alternate bearing by increasing the growth of some spurs so much that they will not set fruit buds in the current year but in the following year. He also considers that pruning, especially in the off year, may stimulate spur, growth, and prevent certain spurs from forming flower buds, thereby promoting annual bearing. Hooker (8) also found that when nitrogen is applied in the fall or late summer, nitrogen and starch content of the tissue is increased the following June at time of fruit bud differentiation.

In a pruning experiment with a large number of York trees, conducted in the off year with and without nitrogen fertilization, Hooker (9) found in the succeeding off year, two seasons later, that a fair yield of fruit was produced where little or none was expected. Trees only pruned averaged 3.5 bushels per tree while trees pruned and fertilized averaged 6.7 bushels, thereby indicating that pruning contributed as much to the result as fertilizing. In an experiment with biennial bearing Yellow Newtowns, Brown (4) was able by means of a rejuvenation treatment consisting of thinning out of trees, fertilizing, and fruit thinning to re-establish annual bearing, and bring about a phenomenal increase in total yield per tree.

Recently the practical approach to the control of biennial bearing has emphasized blossom thinning and early season fruit thinning. Magness *et al.* (10) showed that in Virginia early stages of fruit bud formation can be detected from late June into August, and on ringed branches some degree of blossom differentiation could take place up until 110 days from full bloom. This would indicate that where the carbohydrate supply is favourable, flower bud differentiation can take place much later than is ordinarily expected. Aldrich (1), Aldrich *et al.* (2), Harley *et al.* (5, 6), and Potter (15) have emphasized the importance of increased leaf area in promoting a set of fruit buds in the bearing year. In this connection vigorous condition of the tree is an important factor as mentioned by Bobb *et al.* (3). Where blossom thinning is performed, the percentage of flower clusters that must be removed to permit formation of flower buds in the current season varies with the spur habit of the tree, tree vigour, and other factors. On Newtowns, McCormick (11) reports that defloration of two-thirds or three-quarters of the spurs is sufficient; with Wealthy, Bobb *et al.* (3) claim that a 10- to 12-inch spacing between spurs is necessary.

When performed within 30 to 40 days from time of full bloom, heavy fruit thinning leaving one fruit to 50 to 70 leaves has induced a satisfactory development of flower buds according to the results of Harley *et al.* (5, 6), and Potter (15). When performed later than 40 days from full bloom, results were disappointing.

With both blossom thinning and heavy fruit thinning experiments, annual bearing was restored in the trees concerned, and the total crop for the biennium was greatly increased, sometimes as much as 100%, over

check trees which received no treatment. Moreover it is reported in most instances that by judicious regular thinning in the following seasons the annual bearing habit has been maintained.

PROCEDURE AND RESULTS

Previous Cropping History

Four Newtown trees of pronounced biennial bearing history were used for this experiment. The trees were 20 years old in 1936 when the experiment was started and had been growing in a fertile sandy loam with a continuous alfalfa cover crop. The trees were planted 30 feet apart on the square, were large for their age, in heavy bearing, and with one exception were making 10 or more inches terminal growth annually. All conditions were favourable for heavy production since the trees received annual pruning, were irrigated throughout the summer, and received bountiful pollination from Grimes and Delicious trees in adjacent rows. The previous cropping history of these trees is given in Table 1. Since 1930 these trees had been in marked biennial bearing.

TABLE 1.—PREVIOUS CROPPING HISTORY OF NEWTOWN APPLE TREES USED IN BIENNIAL BEARING EXPERIMENTS

Tree No.	Thinning treatment commenced	Yield in pounds					
		1930	1931	1932	1933	1934	1935
		lb.	lb.	lb.	lb.	lb.	lb.
399	1936	720	325	940	235	1115	165
395	1936	630	52	780	25	990	0
394	1936	815	5	870	230	1020	30
398	1937	145	785	5	860	0	960

Treatments Applied and Time Required to Perform Them

In 1936, the heavy bearing year for 3 of the trees, 3 different thinning treatments were applied with the object of breaking the biennial bearing habit of these trees. In 1937 the fourth tree was treated. The treatments used were as follows:

TREE 399. Fruits thinned 20 inches apart 5 weeks from full bloom.

TREE 395. Tree blossom thinned, removing 5 out of 6 flower clusters in the "pink" stage. Five weeks later the fruits on each spur were thinned to 1 per spur.

TREE 394. Blossoms completely removed from alternate main branches in the "pink" stage.

TREE 398. Same treatment as for Tree 395, only performed in 1937. (This tree somewhat lacking in vigour.)

The length of time required to blossom thin apple trees depends to a great extent upon the stage at which it is done. The most economical time is when the flower clusters are in the pink stage while the individual flower pedicels are still adherent, and have not yet separated (see Figure 1). In this stage each flower cluster may be completely removed with one nip of

the fingers. If the thinning is done earlier, in the cluster bud stage, it is difficult to be certain all flowers are removed from each cluster. If the thinning is delayed until the individual flowers have started to open out, the pedicels of the flowers become separated from one another, usually requiring two or three nips to remove all of them from the cluster, which

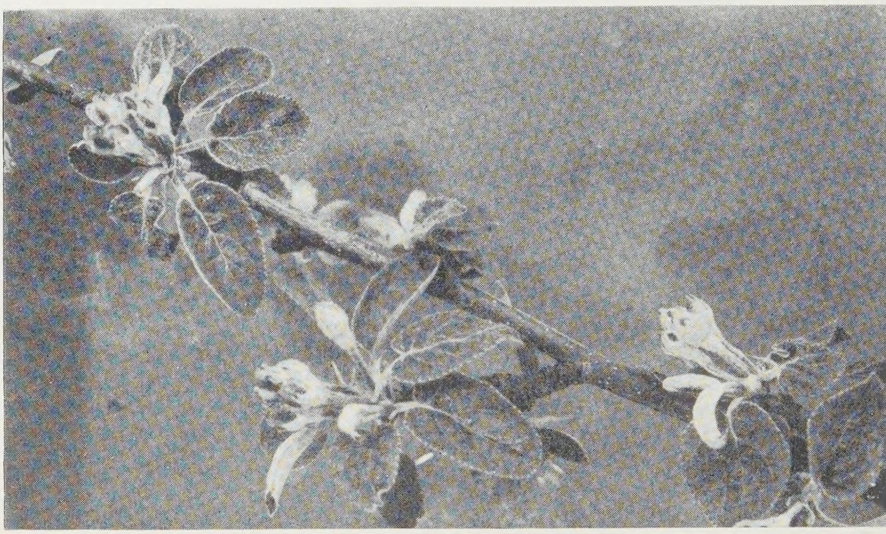

FIGURE 1. Showing flower clusters in the "pink" stage, the most economical time at which to blossom thin.

increases the cost. All flowers must be removed from each thinned cluster in order to render the treatment fully effective. The length of time to perform the different thinning treatments is given in Table 2, along with the time required for commercial 6-inch thinning on corresponding trees.

TABLE 2.—TIME REQUIRED TO THIN EXPERIMENTAL TREES

Tree No.	Treatment	Time required		
		Blossom thinning	Regular thinning 5 weeks from full bloom	Commercial thinning (6-inch)
		hr.	hr.	hr.
399	Thinned 20″ apart 5 weeks from full bloom	0	5.75	2.5
395	Blossom thinned 5 out of 6 spurs	10	2.25	3.0
394	Alternate branches blossoms removed	5	1.75	2.0
398	Blossom thinned 5 out of 6 spurs	8	3.10	2.5

According to these data the initial expense of blossom thinning appears high in comparison with regular 6-inch thinning. Thinning to 20 inches apart 5 weeks from full bloom, however, took only 5.75 hours in comparison

with 2.5 hours for corresponding 6-inch thinning. It should be noted that these drastic treatments were found necessary only in the first year to break the biennial bearing habit and were not repeated in subsequent years.

Percentage of Blossom in Year Following Thinning Treatments

The immediate effect of the treatments applied can be gauged from the flowering performance of the trees in following years. The percentage of the spurs on the experimental trees which flowered in the two succeeding years is given in Table 3. These data indicate that in the 2 years following

TABLE 3.—EFFECT OF THINNING TREATMENTS UPON PERCENTAGE OF SPURS BLOSSOMING IN SUCCEEDING YEARS

Tree No.	Treatment	Percentage of bloom compared with similar "on" year Newtowns	
		1937	1938
		%	%
399	Thinned 20″ apart 5 weeks from full bloom (1936)	40	75
395	Blossom thinned 5 out of 6 spurs (1936)	65	70
394	Alternate branches blossoms removed (1936)—		
	"on" branches	100	5
	"off" branches	20	100
398	Blossom thinned 5 out of 6 spurs (1937)	—	8
Check	Regular 6-inch thinning	0	100

the thinning treatments a good set of fruit buds was secured. In the case of Tree 394 on which alternate branches were completely deflorated in 1936, the deflorated branches influenced the fruiting branches to the extent that a 20% set of flower buds resulted which normally would not have occurred. In later years, a more complete alternation of cropping on the individual branches has resulted. In the case of Tree 398 which was somewhat lacking in vigour, even blossom thinning failed to induce a significant set of flower buds; only about 8% flowering the year following treatment. This emphasizes the importance of tree vigour in carrying out any treatment designed to promote more regular cropping. With Trees 399, 395, and 394, similar satisfactory set of fruit buds has been obtained in 1939 and 1940.

Thinning Treatments Subsequent to Initial Shock Treatments

Since the severe initial thinning treatments carried out in 1936, the trees have been regularly thinned each spring within 5 weeks of full bloom to 1 fruit per spur. Because of the fairly even distribution of bearing and non-bearing spurs, the spacing of the individual fruits has been 6 and 9 inches apart on the average. This thinning has proved adequate to maintain the restored annual bearing habit.

Influence of Thinning upon Cropping Performance.

The three thinning treatments applied to Trees 399, 395, and 394, have returned these trees to the annual bearing condition. The increase in crop in each biennium since the treatment was given is presented in Table 4.

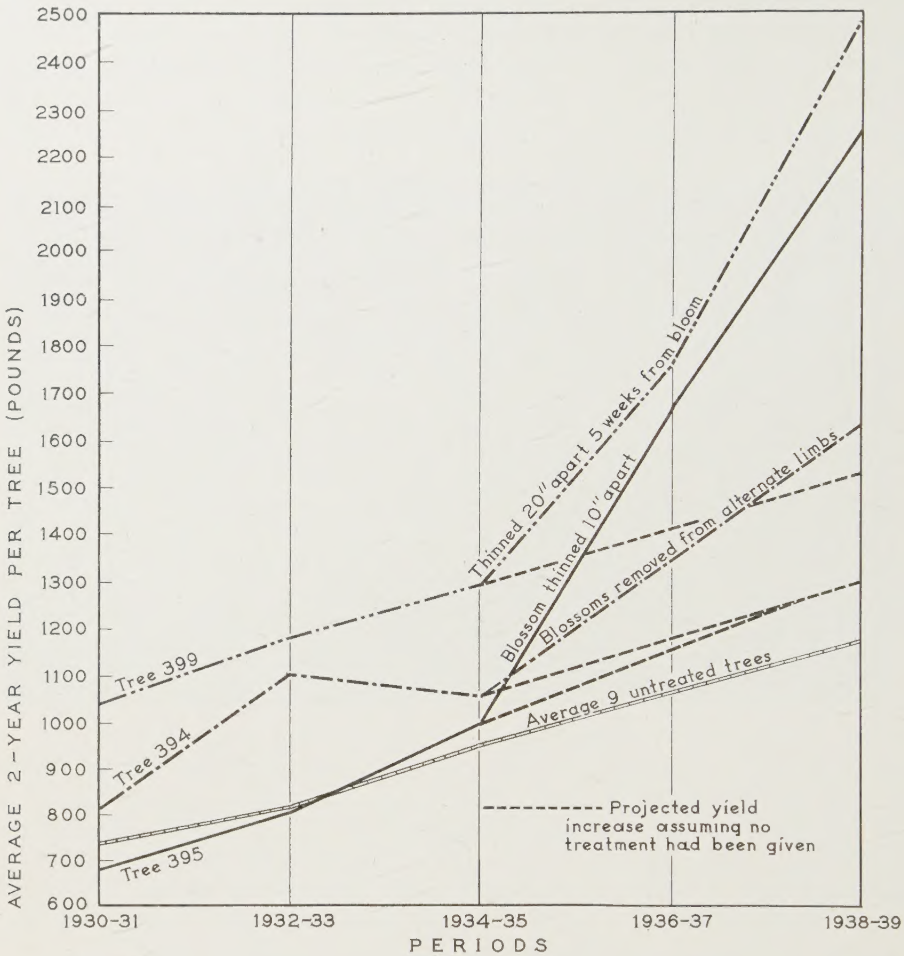

FIGURE 2. Increase in biennium yield of Newtown apples brought about by blossom and early thinning.

In arriving at a sound basis for ascertaining the increase in cropping capacity due to thinning treatment, the natural increase in yield as a result of greater age has been determined for a comparable group of 9 Newtowns of the same age. Based upon the rate at which the cropping capacity of the experimental trees was naturally increasing with age, the projected yield for these trees in the 1938–39 biennium has been computed, assuming that no treatment had been given.

These data have also been plotted in Figure 2. The natural increase in yield during each biennium for each tree and for the group of 9 check trees took a very similar course in all cases. The sharply increased yields following thinning treatments are very striking, particularly with Trees 399 and 395, amounting to 63 and 73% respectively. Alternate branch blossom thinning gave a yield increase of 27%.

TABLE 4.—EFFECT OF THINNING TREATMENTS UPON CROPPING CAPACITY OF NEWTOWNS

Tree No.	Two-year combined yields					Projected yield that would have resulted without thinning in 1938–39	Increase in yield attributed to thinning	Percentage increase
	1930–31	1932–33	1934–35	1936–37	1938–39			
	lb.	lb.	lb.	lb.	lb.	lb.	lb.	%
399	1045	1175	1280	1745	2480	1520	960	63
395	682	805	990	1645	2240	1290	950	73
394	820	1100	1050	1335	1630	1285	345	27
Average 9 checks								
	774	815	949	1056	1168	—	—	—

Effect of Thinning Treatments on Size of Fruit

The effect of blossom thinning upon the size of the fruit produced has been equally interesting. At picking, the fruits were divided into three size grades, over 3 inches, $2\frac{1}{2}$ to 3 inches, and $2\frac{1}{4}$ to $2\frac{1}{2}$ inches. Apples smaller than $2\frac{1}{4}$ inches, windfalls, and wormy fruits were classed as culls. The average grade-out of non-blossom thinned biennial bearing trees in their on year is also shown. The data are presented in Table 5.

TABLE 5.—EFFECT OF THINNING TREATMENTS ON SIZE OF FRUIT

Tree No.	Treatment	Year	Size and yield in pounds per tree				Total
			Over 3″	$2\frac{1}{2}$ – 3″	$2\frac{1}{4}$–$2\frac{1}{2}$″	Culls	
			lb.	lb.	lb.	lb.	lb.
399	Thinned 20″ apart 5 weeks from full bloom. Since 1936 thinned to 1 fruit per spur.	1936	470	375	10	0	855
		1937	210	600	15	65	890
		1938	380	735	10	240	1365
		1939	470	405	15	225	1115
		Ave.	382	529	12	133	1056
395	Blossom thinned 10″ apart. Since 1936 thinned to 1 fruit per spur.	1936	480	375	20	–	875
		1937	210	490	–	70	770
		1938	550	503	10	150	1213
		1939	355	465	25	180	1025
		Ave.	399	459	14	100	972
394	Alternate branches stripped of blossoms. Since 1936 thinned to 1 fruit per spur.	1936	330	270	5	–	605
		1937	245	430	10	55	740
		1938	245	555	5	90	895
		1939	240	310	30	155	735
		Ave.	265	391	12	61	729
Check	6-inch commercial thinned trees, on year	1936	176	493	74	57	800
		1937	41	422	233	87	783
		1938	14	823	210	82	1129
		1939	33	674	123	142	972
		Ave.	66	603	160	92	921

It is evident that the proportion of large size apples from the experimentally thinned trees is much greater than on check biennial bearing trees in their on year. The bulk of the fruit on the check trees fell into the $2\frac{1}{2}$- to 3-inch classification, while on the experimental trees a considerable portion of the fruit fell into the over 3-inch classification. Moreover, ever since the blossom thinning treatment in 1936, each successive crop has shown a strong tendency to run to large sizes. This tendency toward production of large size apples, which in the Newtown variety bring rather poor returns, is the chief disadvantage thus far encountered in annual cropping trees. Whether or not the large increase in yield with annual as compared with biennial bearing trees is sufficient to more than offset the economic loss due to an increased proportion of large sized fruit is yet to be determined.

Blossom Thinning Experiments in Commercial Orchards

In May 1938 a blossom thinning experiment was undertaken in a commercial orchard in Summerland. Five 25-year-old Newtown trees in their full bearing year were blossom thinned in the cluster bud stage, and a record kept of the time required to do this work. This varied from $9\frac{1}{4}$ to $11\frac{3}{4}$ hours averaging 11 hours per tree. The time required for later thinning to one fruit per spur was not recorded.

The previous cropping history of these trees was one of complete biennial bearing. With the exception of one tree which was deficient in vigour, the blossom thinning treatment has converted them into the annual bearing condition, and in 1940, the third cropping year since the treatment was given, a satisfactory crop is again promised. The operator of the orchard is satisfied that conversion of his trees to the annual bearing condition by blossom thinning has increased his yield, but he has obtained a very high percentage of large size fruit.

Another blossom thinning experiment with Winesap in a commercial orchard was started in the spring of 1938. The trees were about 20 years old, and were in their on year at the time the experiment was started. The cropping history of the trees for the two years prior to the start of the experiment is given in Table 6 together with the yields for 1938, the year the thinning was done, and the succeeding year.

TABLE 6.—EFFECT OF BLOSSOM THINNING UPON CROPPING CAPACITY OF BIENNIAL BEARING WINESAPS

Lot number	Row number	Tree number	Yield in different years			
			1936	1937	1938	1939
			bx.	bx.	bx.	bx.
6	3	2	20	4	21	14
6	3	10	24	1	9	22
6	4	18	36	5	27	37
6	7	5	33	3	27	20
6	11	2	13	2	37	32
6	19	8	60	2	45	21
Total			186	17	166	146
Total for two years			203		312	

Increase in yield — 54%

The almost complete biennial bearing character of these trees prior to blossom thinning is shown. Blossom thinning restored these trees to an almost uniform bearing condition. In 1940, the third year since blossom thinning, these trees again carry a good crop. The increase in yield per biennium following blossom thinning amounted to 54%.

DISCUSSION

Evidence is presented that blossom thinning and extra heavy early thinning treatments are effective in re-establishing the annual bearing habit in biennial bearing Newtown and Winesap apple trees. The results of this experiment and other experiments indicate that in order for such shock treatments to be effective the trees must be in a vigorous condition at the time the treatment is given, and must be kept in a vigorous condition in order for the effect to be lasting. However, while with the Newtown and Winesap varieties yields were greatly increased by the re-establishment of annual bearing, the apples produced tended to run too large to fall into the most profitable market sizes. For example, 30 to 40% of the Newtown apples were over 3 inches in diameter. It might be possible to produce smaller sized Newtown apples on these trees by reducing the nitrogen supply. However, this procedure would reduce the leaf area and formation of new fruiting wood, with the result that the trees would probably revert once more into biennial bearing. Thus, it seems that it is almost impossible to have moderate cropping annual bearing trees which at the same time produce small to medium sized fruits. With varieties such as Newtown, McIntosh, and Cox Orange, in which small sized apples are most profitable, the question to decide is whether it would pay better to have biennial bearing trees producing a crop of small to medium size apples every other year, or to have annual bearing trees producing considerably greater total yields of moderate to large sized apples.

With varieties such as Delicious, Rome Beauty, and Duchess, where moderate to large sized apples bring the best returns, blossom thinning or any other method of maintaining trees in vigorous annual bearing appears to be desirable. When Rome Beauty and Delicious get into biennial bearing, they produce excessive crops of small, poor coloured, late maturing fruit. When these trees are maintained in a vigorous annual bearing condition they produce fruit of the best size and quality.

The extra cost of special thinning treatments designed to correct biennial bearing is heavy the year they are applied, and may cost three dollars or more per tree. However, since these treatments result in a large increase in yield and need not be repeated provided the trees are maintained in a satisfactory state of vigour and receive adequate thinning, the extra initial expenditure may be well repaid. With varieties in which large sized fruits are demanded, special thinning treatments may be decidedly profitable.

SUMMARY

1. Blossom thinning and early extra heavy thinning treatments given to Newtown and Winesap apple trees restored the regular annual fruiting condition.

2. The restored annual fruiting condition has been maintained by means of thinning to one fruit per spur in subsequent years.

3. Total yields were greatly increased on trees converted from the biennial bearing to the annual bearing condition.

4. In the Newtown variety, size of fruit was greatly increased, so that much of the crop fell into unprofitable size grades.

5. It is suggested that the practical value of thinning treatments designed to promote regular annual cropping will depend on the optimum size of fruit desired in each variety.

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TRANSFER OF THE BULB NEMATODE—*DITYLENCHUS DIPSACI* FROM *TROPAEOLUM POLYPHYLLUM*, A NEW HOST, TO POTATOES[1]

R. J. HASTINGS[2]

Dominion Laboratory of Plant Pathology, Saanichton, B.C.

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In October, 1939, two small shipments of *Tropaeolum polyphyllum* Cav. tubers arrived at Vancouver, British Columbia, from Holland and were found infested with nematodes, identified as *Ditylenchus dipsaci*. The tubers were in varying stages of decay and afforded an opportunity for studying the symptoms of infestation. Externally, there were no symptoms except that the affected portions of the tubers became soft and yielded to gentle pressure. When the tubers were cut longitudinally the infested areas were found to be punky in texture with brownish pink discoloration. In most cases the infestations seem to have started in the stem end and proceeded down the centre of the tuber and also along the vascular system resulting in large fissures. The nematodes found in these areas were practically all *Ditylenchus dipsaci* species and included adults, larvae and eggs. The populations numbered several thousand per cubic centimeter of tissue. The host list of the bulb nematode compiled by Steiner and Buhrer (1) in 1932 does not include *Tropaeolum*.

TRANSFER OF POPULATION FROM *TROPAEOLUM* TO POTATO

The bulb nematode is a serious pest of potatoes in England, Holland, and other European countries, but up to the present has not been observed attacking potatoes in Canada although it is prevalent in British Columbia as a serious pest of bulbs. The absence of infestation in potatoes in Canada must be attributed to the fact that there are specialized strains of the bulb nematode, and a potato strain is apparently non-existent in British Columbia. In support of this conclusion, numerous attempts have been made without success, to transfer the narcissus strain of the bulb nematode to potatoes at Saanichton.

The possibility that a tuber strain such as that found in *Tropaeolum* might be capable of attacking another tuber crop like potatoes suggested the advisability of studying transfers from one crop to the other.

A number of infested *Tropaeolum* tubers were macerated and used to inoculate two flats 6 inches × 12 inches × 18 inches filled with steam sterilized soil. In each flat 6 potato sets, each a different variety, were planted, and the flats were kept through the winter in the greenhouse until the plants matured and the crops were harvested.

The tubers unfortunately also became affected with early blight, *Alternaria solani* (E. & M.) Jones and Grant, but nearly all the numerous sunken lesions that were examined contained specimens of the bulb nematode. In the variety Katahdin, an infestation proceeding from the stem

[1] Contribution No. 630, from the Division of Botany and Plant Pathology, Science Service, Dominion Department of Agriculture, Ottawa, Canada.
[2] Graduate Assistant.

end into the heart of the tubers yielded a population of thousands of adults, larvae and eggs, indicating that the nematodes not only transferred to the potato but found conditions favourable for the development of a serious infestation. The tabulated data show the relative susceptibility of the varieties tested as judged by the nematode populations found in the water suspensions of macerated potato tissue.

TABLE 1.—SUSCEPTIBILITY OF POTATO VARIETIES TO ATTACK BY THE BULB NEMATODE FROM TROPAEOLUM TUBERS

Variety	Nematode population found				Relative susceptibility
	Male	Female	Larvae	Eggs	
Early Rose	+	–	–	–	Very slight
Warba	+	++	++	+	Highly susceptible
Netted Gem	–	–	–	–	Resistant
Raleigh	+	+	+	–	Slight
Green Mountain	++	++	++	++	Highly susceptible
White Rose	+	+	++	+	Moderately susceptible
Houma	+	+	+	+	Moderately susceptible
Sutton's Reliance	–	+	–	–	Very slight
Early Epicure	–	+	+	+	Moderately susceptible
Beauty of Hebron	–	–	+	–	Very slight
Irish Cobbler	+	+	+	++	Moderately susceptible
Katahdin	+++	+++	++++	+++	Very highly susceptible

These results indicate that the bulb nematode from *Tropaeolum* can become a serious pest of potatoes, and nematode infested tuber crops may generally be considered a potential source of danger to the potato industry.

SUMMARY

Symptoms of a bulb nematode infestation on *Tropaeolum polyphyllum* a new host, are described. Positive transfers have been made from *Tropaeolum* to potatoes, the varieties Katahdin, Green Mountain and Warba being highly susceptible, White Rose, Houma, Early Epicure and Irish Cobbler moderately susceptible, and Early Rose, Raleigh, Sutton's Reliance and Beauty of Hebron, slightly susceptible. No transfers were successfully made to Netted Gem.

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YIELD AND CHEMICAL COMPOSITION OF PURE SPECIES, STRAINS AND MIXTURES OF GRASSES, CLOVERS AND ALFALFA[1]

O. McConkey[2]

Ontario Agricultural College, Guelph, Ontario

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The object of this experiment was to determine the relative yield of dry matter, protein, calcium, and phosphorus of different pure species, strains, and mixtures of grasses, clovers and alfalfa for pasture and hay production.

The technique followed was to cut with a fine toothed sickle-mower five times a year. Two composite samples of 2 pounds each were taken for the determination of dry matter, protein, calcium and phosphorus content. Botanical analyses were taken at each cutting to determine the successional changes in the flora. The same series was subjected to grazing under practical field conditions and the botanical changes studied.

TABLE 1.—COMPARATIVE YIELD OF PURE SPECIES

Species	Percentage and pounds per acre (Average 4 years, 1935–38)						
	Dry matter	Crude protein		Calcium		Phosphorus	
		%	lb.	%	lb.	%	lb.
1. Timothy	5189	17	888	0.87	45	0.44	24
2. Brome (Common)	5030	18	943	.87	43	.44	23
3. Orchard (Common)	4985	16	831	.84	40	.52	27
4. Crested wheat (Fairway)	4710	19	928	1.05	52	.45	22
5. Meadow fescue	4700	18	840	.99	47	.53	27
6. Reed Canary	4587	18	824	.83	38	.51	24
7. Brome (Parkland)	4553	18	824	.91	43	.45	21
8. Meadow foxtail	4426	18	800	.89	40	.43	20
9. Alfalfa	4321	25	1140	1.95	85	.51	27
10. Red fescue (Olds)	4137	15	615	.91	36	.39	18
11. Orchard (Akaroa)	4093	17	735	.91	36	.48	20
12. Red top	3849	16	641	.97	37	.41	17
13. Canadian blue	3686	17	634	.89	34	.43	16
14. Kentucky blue	3569	15	553	.85	29	.43	16
15. Red fescue (N.Z.)	3378	16	563	.76	25	.43	16

COMPARATIVE YIELD OF PURE SPECIES

Alfalfa averaged 6,641 lb. of dry matter and 1,829 lb. of crude protein for two years, after which it killed badly because of the close clipping, thus reducing the 4-year average.

There was a comparatively low yield of dry matter, protein and minerals from Kentucky, Canadian bluegrass, and Red Top. These are the dominant species in old unimproved pastures in Ontario.

[1] Contribution from the Field Husbandry Department, Ontario Agricultural College, Guelph, Ontario.
[2] Associate Professor of Field Husbandry.

Alfalfa showed a high protein and mineral content in comparison with the pure grasses. Considering nutritive value, the necessity of growing more well balanced legume-grass mixtures is pointed out. Too many hay and pasture crops are deficient in legumes.

TABLE 2.—INFLUENCE OF 2 LB. WILD WHITE CLOVER

Species	Percentage and pounds per acre (Average 4 years 1935–38)						
	Dry matter	Crude protein		Calcium		Phosphorus	
		%	lb.	%	lb.	%	lb.
Timothy	5189	17	888	0.87	45	.44	24
Timothy + 2 lb. Wild white	*5735*	18	*1042*	.96	*56*	.45	*27*
Kentucky blue	3569	15	553	.85	29	.43	16
K. blue + 2 lb. Wild white	*4660*	16	*769*	.91	*43*	.43	*21*
Canadian blue	3686	17	634	.89	34	.43	16
C. blue + 2 lb. Wild white	*4958*	19	*970*	1.07	*55*	.44	*22*
Orchard (Akaroa)	4093	17	735	.91	36	.48	20
Orchard (Akaroa) + 2 lb. Wild white	*4603*	18	*863*	.93	*43*	.49	*23*

INFLUENCE OF WILD WHITE CLOVER

Table 2 shows an increase in yield in *protein* and *mineral* content by the addition of 2 lb. wild white clover. The rapid soil test shows a significant increase in nitrate nitrogen under the clover plots. Wild white clover proved to be compatible with the grasses in the following order: timothy, Canadian blue, Kentucky blue, Orchard. A grass with an open bottom facilitates the spread of white clover, while a close sward forming grass, i.e., Kentucky blue and creeping Red fescue, inhibits the spread of this clover. The vigorous growing canopy growth of Orchard grass shades out White clover. The percentage of white clover fluctuated greatly with the season and year, being largely dependent on ample moisture. Variation in contribution to the sward varied from 1 to 48%.

Despite the wide variation in the contribution of wild white clover to yield and nutritive value over the different seasons and years, the inclusion of one or two pounds per acre in a pasture mixture which is to be closely grazed is justified on a good moisture holding soil type under the climatic conditions of western Ontario.

TABLE 3.—COMPARISON OF STRAINS OF WHITE CLOVER*

Species	Percentage and pounds per acre (Average 4 years 1935–38)						
	Dry matter	Crude protein		Calcium		Phosphorus	
		%	lb.	%	lb.	%	lb.
Ladino	4843	18	898	1.23	61	.41	20
N.Z. wild white	4742	17	838	1.04	50	.43	22
Commercial white clover	4296	17	734	.97	42	.42	19
Wild white (Kent)	4106	16	658	.99	40	.42	18
Morso	3893	17	661	.98	38	.41	17
Kentucky blue 4, Timothy 6	3747	16	621	1.00	37	.43	18

* 2 lb. clover in basal mixture of Kentucky blue 4 lb., timothy 6 lb.

STRAINS OF WHITE CLOVER

Table 3 shows that New Zealand wild white clover, Ladino, and Kentish strains have proven to be persistent, while commercial White Dutch has practically disappeared at the end of four years under mowing treatment, but it should be observed that under natural grazing conditions with this same series, Wild White Clover proved the most persistent.

TABLE 4.—INFLUENCE OF PASTURE TREATMENT VERSUS HAY AND AFTERMATH ONE YEAR—PASTURE AFTERWARDS

Species and mixtures		Percentage and pounds per acre (Average 4 years 1935–38)						
		Dry matter	Crude protein		Calcium		Phosphorus	
			%	lb.	%	lb.	%	lb.
Cut 5 times a year								
Kentucky blue		3569	18	553	0.91	29	0.45	16
Timothy		5189	17	888	.87	45	.44	24
Alfalfa		*5605	25	1427	2.05	135	.60	43
1. Alfalfa Red top Alsike Kentucky blue White Dutch Timothy	5 2 2 4 1 6	6823	20	1454	1.33	119	.47	44
Hay and aftermath 1 year—then pasture, i.e., cut 5 times a year								
2. Alfalfa Red clover Alsike Timothy Orchard	5 4 2 7 4	8475	18	1614	1.36	131	.43	38
3. Timothy Alfalfa Ladino Wild white	8 5 1 2	8482	21	1844	1.68	155	.42	39
4. Orchard Alfalfa Ladino Wild white	12 5 1 2	8617	21	1878	1.58	150	.44	41

* Average of 3 years.

PASTURE TREATMENT

A common farm practice in the management of meadows in Ontario is to take a hay crop in the year following seeding, and utilize the aftermath for pasture, followed by pasture for one, or perhaps two years.

Although the mixtures are not strictly comparable, there is ample evidence to show that the practice of cutting the first crop early for hay,

and utilizing the aftermath for pasture furnishes more food nutrients per acre than continued pasturing from the beginning.

Ladino clover has proven to be promising in the foregoing mixtures. It fills the bottom and is more persistent than red clover and Alsike.

The superiority of mixtures over single species for producing food nutrients, especially over the low yielding Kentucky blue, is clearly shown.

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A COMPARISON OF THE ORGANIC MATTER OF UNCULTIVATED AND CULTIVATED APPALACHIAN UPLAND PODSOL SOILS[1]

H. F. SALISBURY[2] AND W. A. DELONG[3]

Macdonald College, Quebec

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Considerable investigation of the soils characterized by McKibbon and Gray (6) as Appalachian upland podsols has been in progress since 1931, most of studies being carried on in the vicinity of Sawyerville, Compton County. Some of the more practical results of these investigations have recently been summarized (2). It has been shown that the cultivated soils of this group are relatively high in organic matter which is apparently comparatively inert in nature and correspondingly difficult to decompose (4, 6). The present study is an attempt to determine what changes, if any, the organic matter of these soils may have undergone as a result of deforestation and subsequent cultivation for a period of 75 years or more.

The usual rotation practised in the district under survey consists of a crop of oats followed by continuous hay until the yield of the latter becomes unsatisfactory. In the past liming has not been practised, and the principal fertilizer applied has been barnyard manure. The cultivated areas are thus essentially under a system of grassland management. It has recently been emphasized (13) that the average soil temperature during the summer is markedly increased when the forest cover is removed. Such a temperature change would be expected to affect appreciably the amount, and perhaps also the nature, of the soil organic matter. In view, therefore, of the difference in soil climate resulting from deforestation, and in view also of the changed character of the vegetative cover, it was thought that fundamental changes in the amount and nature of the soil organic matter might have occurred. This surmise was based on the belief that the new conditions under cultivation had been operating long enough to bring the soil organic matter into equilibrium with them.

Previous studies of the changes brought about by the cultivation of soils have largely been confined to determination of total carbon and total nitrogen in the cropped and in adjacent uncropped soils. In the present investigation, however, it was thought desirable to obtain, in addition, more detailed information on the possible changes in the nature of the organic matter. For this purpose Shewan's modification (12) of the Waksman-Stevens procedure (14) was employed with minor changes in the technique. Shewan used this method in the study of the organic matter in the profiles of forest soils, while Waksman and Hutchings (15) have employed the original procedure for this purpose, and also to study the changes brought about in soil organic matter under different manurial treatments. However, so far as the authors are aware, similar studies on cropped as compared with adjacent uncropped soils have not previously been made.

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[1] Based on a thesis presented by H. F. Salisbury to the Faculty of Graduate Studies of McGill University in partial fulfilment of the requirements for the degree of Master of Science in Agricultural Chemistry.
Contribution from the Department of Chemistry, Macdonald College, P.Q., Canada, with assistance from the Department of Agriculture of Quebec, Que.

[2] Formerly Graduate Assistant in Soil Fertility.

[3] Assistant Professor of Chemistry.

EXPERIMENTAL MATERIAL

The soil samples studied were taken from six sites in the vicinity of Sawyerville, Compton County, Quebec, during the summer of 1938. At each site two samples were taken, one from a cultivated soil and the second from either a forested soil or a permanent pasture. These paired samples were taken from points usually less than one hundred yards distant from each other. Each sample was obtained by digging two trenches about 20 feet apart, about 7 inches deep, and several feet long, and taking spade slices from the vertical sides of these.

The fields from which the cultivated soil samples were collected were deforested 75 or more years ago, and, with the exception of that from the S farm, have, as nearly as could be ascertained, been under tillage ever since. The cultivated area at the S farm has been in pasture for at least the major part of the time since being cleared and was taken into cultivation last in 1936.

The forested locations chosen did not carry an unaltered vegetative cover. Nevertheless, they are representative of those which must be selected if any study of this kind is to be attempted in this region. It seems unlikely that the soil itself at these various locations has suffered any greater disturbance than might be brought about by natural agencies, such as the falling of limbs or tree-trunks, or the uprooting of trees by wind. At the H farm the forested soil sample was taken from an improved sugar bush. The improvement of this bush consisted in the removal of most of the native tree species except the sugar maple, and in fencing the area against live-stock. The dominant undergrowth here consisted of various species of fern, prominent among which were *Thelypteris phegopteris*, *Onoclea sensibilis* and *Thelypteris dryopteris*. Other plant species of importance in the undergrowth were *Laportea canadensis* and *Aralia racemosa*. At the S farm the forested soil sample was taken from an ordinary sugar bush typical of most of those found in the Eastern Townships region of Quebec. The tree cover here consisted almost entirely of sugar maple. This site had been pastured regularly; the undergrowth was sparse, and consisted mainly of native grasses and various herbs. At the G farm the forest growth consisted mainly of sugar maples and beech of various ages. This woodlot had evidently been thinned from time to time but apparently no extensive cutting had taken place for a considerable number of years. This site was the most nearly representative of actual forest conditions of the three. Here the undergrowth was very variable and without any predominant herb or shrub; *Acer pennsylvanicum*, *Viburnum lantanoides* and *Aralia racemosa* appeared to be the commonest shrubs.

The pasture soil samples taken at the H farm were obtained from a field which had been plowed some 35 years earlier but which had been abandoned to indigenous herbage since that time. One of these, 7A, was taken beside a moss hummock such as is characteristically found in neglected pastures in this region. Some mixed fertilizer had been applied to this pasture but no lime. At the McK farm the pasture from which the samples were taken probably had never been plowed. At both sites the vegetative cover consisted of various native grasses and herbs (10) and

wild white clover. There was a considerably greater proportion of the latter in the sward of the H pasture, presumably as a result of the recent use of artificial fertilizers at this site.

The various soil samples studied, with their locations and the percentages of material refusing the one millimeter sieve, are given in Table 1. The discarded material was almost entirely inorganic in nature except for Sample 1, in which instance it consisted largely of coarse particles of undecomposed plant material.

TABLE 1.—PERCENTAGE OF ORIGINAL SAMPLE REFUSING THE ONE MILLIMETER SIEVE

Sample No.	Location	Type of sample	Detritus
			%
1	H farm	Forested	3.8
2	H farm	Cultivated	15.9
3	G farm	Forested	16.1
4	G farm	Cultivated	16.7
5	S farm	Forested	26.3
6	S farm	Cultivated	19.0
7	H farm	Pastured	19.1
8	H farm	Cultivated	14.1
7A	H farm	Pastured	36.4
9	McK farm	Pastured	17.5
10	McK farm	Cultivated	9.3

ANALYTICAL METHODS

Moisture was determined by drying at 105° C., and loss on ignition by heating the oven-dried sample at 550° C. All determinations of nitrogen were made by the Kjeldahl-Gunning-Arnold method, and of carbon by dry combustion, both as outlined in the Official Methods of the A.O.A.C. (11). Copper sulphate was used as the catalyst in the nitrogen determinations.

In the fractionation of the soil organic matter Shewan's modification of the Waksman-Stevens procedure (12) was employed with minor changes in technique designed to give increased accuracy and convenience. These changes were as follows:

(*a*) The lipid fraction was dried to constant weight over anhydrous calcium chloride at room temperature and under reduced pressure (water pump). This modification was introduced after experiments had indicated that there was present material volatile at 105° C., the drying temperature used by Shewan.

(*b*) After each extraction process the total residue was used for the next operation, the amount of the necessary reagent being increased proportionately.

(*c*) In the determination of the reducing power of the acid hydrolyzates, invert sugar (prepared as needed by acid inversion of C.P. sucrose at room temperature) was used as the sugar standard in place of glucose; the size of the

aliquot taken for the determination of the reducing power was also increased to 100 ml., equivalent to 2.5 grams of the air-dried soil sample. It may be noted that the concentrations of the hydrochloric acid and sulphuric acid solutions used for hydrolyzing the "hemicellulose" and "cellulose" fractions were approximately 0.85 and 8.3 per cent (by weight) respectively.

(*d*) In the determination of amide nitrogen the method followed was that recommended by Morrow (8).

TABLE 2.—COMPOSITION OF SAMPLES AS PERCENTAGE OF AIR-DRY SOIL

Sample No.	Location	Moisture	Nitrogen	Carbon	C/N	C×1.724	Loss on ignition
Forested samples:							
1	H farm	5.95	0.388	5.19	13.4	8.95	12.05
3	G farm	3.57	0.247	4.33	17.5	7.46	9.38
5	S farm	3.14	0.293	6.16	21.0	10.61	13.64
Means		4.22	0.309	5.23	17.3	9.01	11.69
Average deviations		±1.15	±0.052	±0.62	±2.6	±1.10	±1.54
Cultivated samples:							
2	H farm	2.28	0.254	3.10	12.2	5.34	6.63
8	H farm	1.97	0.220	3.31	15.0	5.70	6.95
4	G farm	2.90	0.260	4.11	15.8	7.08	8.75
6	S farm	2.24	0.250	3.84	15.4	6.62	8.57
10	McK farm	2.11	0.281	4.79	17.1	8.26	10.31
Means		2.31	0.253	3.83	15.1	6.60	8.24
Average deviations		±0.24	±0.014	±0.50	±1.2	±0.86	±1.16
Pastured samples:							
7	H farm	2.61	0.220	3.48	15.8	6.00	8.02
7A	H farm	2.29	0.245	3.30	13.4	5.68	8.28
9	McK farm	3.27	0.232	4.03	17.4	6.94	9.68
Means		2.72	0.232	3.60	15.5	6.21	8.66
Average deviations		±0.36	±0.008	±0.28	±1.1	±0.49	±0.68

The reducing powers of the hydrochloric and the sulphuric acid hydrolyzates, calculated as invert sugar, are designated as "hemicellulose" and as "cellulose" respectively.

RESULTS AND DISCUSSION

The analytical results for moisture, total carbon, total nitrogen, organic matter (C × 1.724), and loss on ignition as percentages of air-dried soil are given in Table 2. The mean values with their average deviations have been calculated for the results obtained in the analysis of the three series of samples, forested, cultivated and pastured. These mean values are presented to give a measure of the variability of the samples in the different series, and to give some indication of the possible significance of the differences in the values reported for these series. In view of the small number of samples studied a more exact statistical treatment does

not appear to be justified. In the ensuing discussion attention is drawn to certain differences which, on the basis of magnitude and consistency, appear to be significant.

Examination of Table 2 shows that when the samples of forested and cultivated soils are considered by pairs (1 and 2, 3 and 4, 5 and 6), the usual observation that cultivation reduces the carbon and the nitrogen contents of soils is confirmed, except in the instance of the nitrogen content of the G farm soils. The greater reduction in carbon than in nitrogen content with the consequent narrower C/N ratio in the cultivated than in the forested members of the pairs is also in accord with general experience. The C/N ratios for these soils are considerably greater than the values reported by Motkin (9) for cultivated podsols in Russia. The pastured samples proved to be closely similar to those from the cultivated areas, as perhaps might be expected from the nature of the crop rotation generally followed in this region.

In Table 3 values for the amounts of the component fractions of the organic matter are given on the basis of the percentages found in the air-dry laboratory samples. It should be noted that throughout this paper the terms, "lipids"; "hemicellulose"; "cellulose"; "lignin" and "protein" have the significance usually accorded to them in studies of this nature. The use of these terms does not imply either that the fractions so designated consist solely of the chemical substances of these classes, or that the recovery of the chemical compounds of these classes has been quantitative.

TABLE 3.—ORGANIC FRACTIONS AS PERCENTAGE OF AIR-DRY SOIL

Sample No.	Location	Moisture	Carbon × 1.724	Lipids	Water-soluble	Hemi-cellulose	Cellulose	Lignin	Protein
Forested samples:									
1	H farm	5.95	8.95	0.24	0.32	1.33	0.75	3.22	2.27
3	G farm	3.57	7.46	0.25	0.34	0.82	0.49	2.68	1.59
5	S farm	3.14	10.61	0.50	0.61	0.89	0.74	3.43	1.88
Means				0.33	0.42	1.01	0.66	3.11	1.91
Average deviations				±0.11	±0.12	±0.21	±0.11	±0.29	±0.24
Cultivated samples:									
2	H farm	2.28	5.34	0.25	0.26	0.77	0.50	1.17	1.52
8	H farm	1.97	5.70	0.25	0.26	0.72	0.37	1.42	1.54
4	G farm	2.90	7.08	0.28	0.30	0.85	0.61	2.15	1.63
6	S farm	2.24	6.62	0.26	0.32	0.78	0.58	1.72	1.62
10	McK farm	2.11	8.26	0.34	0.45	0.85	0.21	2.67	1.79
Means				0.28	0.32	0.79	0.45	1.83	1.62
Average deviations				±0.028	±0.054	±0.044	±0.13	±0.47	±0.12
Pastured samples:									
7	H farm	2.61	6.00	0.34	0.27	0.71	0.43	1.57	1.44
7A	H farm	2.29	5.68	0.41	0.52	0.77	0.54	1.18	1.46
9	McK farm	3.27	6.94	0.29	0.27	0.62	0.16	1.55	1.53
Means				0.35	0.35	0.70	0.38	1.43	1.48
Average deviations				±0.04	±0.11	±0.05	±0.14	±0.17	±0.04

TABLE 4.—ORGANIC FRACTIONS AS PERCENTAGE OF TOTAL ORGANIC MATTER (C × 1.724)

Sample No.	Location	Organic matter (C×1.724)	Lipids	Water-soluble	Hemi-cellulose	Cellulose	Lignin	Protein	Sum as percentage of total organic matter
Forested samples:									
1	H farm	8.95	2.65	3.58	14.81	8.36	35.95	25.38	90.73
3	G farm	7.46	3.38	4.56	10.95	6.53	35.91	21.31	82.64
5	S farm	10.61	4.70	5.74	8.41	6.99	32.32	17.69	75.85
Means			3.58	4.63	11.39	7.29	34.72	21.46	82.74
Average deviations			±0.75	±0.74	±2.28	±0.71	±1.61	±2.61	±4.99
Cultivated samples:									
2	H farm	5.34	4.66	4.81	14.40	9.37	21.95	28.54	83.75
8	H farm	5.70	4.33	4.47	12.65	6.51	24.90	27.06	79.92
4	G farm	7.08	3.90	4.28	12.03	8.63	30.34	23.00	82.18
6	S farm	6.62	3.96	4.83	11.72	8.82	25.97	24.43	79.73
10	McK farm	8.26	4.06	5.42	10.31	2.58	32.26	21.64	76.27
Means			4.18	4.76	12.22	7.18	27.08	24.93	80.37
Average deviations			±0.25	±0.31	±1.04	±2.11	±3.37	±2.29	±2.05
Pastured samples:									
7	H farm	6.00	5.63	4.50	11.79	7.10	26.15	24.00	79.17
7A	H farm	5.68	7.17	9.08	13.54	9.43	20.79	25.80	85.81
9	McK farm	6.94	4.16	3.82	9.00	2.28	22.33	22 00	63.59
Means			5.65	5.80	11.44	6.27	23.09	23.93	76.19
Average deviations			±1.01	±1.31	±1.63	±2.66	±2.04	±1.29	±8.40

On comparing the paired forested and cultivated samples as before it is seen that the only consistent difference is a lower "lignin" content in the cultivated soils. When these groups are compared on the basis of their mean values for this component this difference seems significant. When the mean values for the three series of samples are compared, an indication that the "hemicellulose" as well as the "lignin" content of the pastured soils may be lower than that of the forested soils is observed. The pasture samples again agree more closely with the cultivated than with the forested soils in their analysis. The difference in "protein" contents of the forested and the pastured soils may be significant.

A general tendency in all three series of samples for a high "lipid" content to be associated with a high content of water-soluble organic matter is to be noted. However, the results obtained by Waksman and Hutchings (15) for soil from plots receiving different manurial treatments indicate that a high "lipid" content is not necessarily associated with a large amount of water-soluble organic matter.

It may also be noted that the "hemicellulose" content is in all instances considerably greater than the "cellulose" content. This accords with the previous observation of Motkin (9) for cultivated Russian podsols.

The results of the present study also confirm the findings of Motkin with regard to the approximate equality of the "lignin" and "protein" contents of cultivated podsols. However, in the present instance this equality may be more apparent than real, as is pointed out in the subsequent discussion of the possibility of solution of a fraction of the "lignin" in dilute acid solutions.

In Table 4 the results for the various fractions determined are presented as percentages of the total organic matter (C $\times$ 1.724).

Examination of Table 4 shows that, on the basis of the percentages of the various fractions in the organic matter, as well as on that of the amounts of these components in the air-dry soil, the only possible significant difference between the samples of the various series is in the "lignin" content. The difference between the forested and the pastured soils in respect of this fraction is particularly noteworthy. However, although not regarded as significantly different the proportion of "protein" in the organic matter tends to be higher in the cultivated and in the pastured than in the forested soils. This trend is consistently shown by the paired samples of forested and cultivated soils (1 and 2, 3 and 4, 5 and 6). With respect to "cellulose" content the samples from the McK farm are abnormally low. No explanation can be offered for this fact.

It will be noted that the recovery of the organic matter in terms of the sum of the various fractions determined is relatively low. This may be due to solution of "lignin" in the acids used for hydrolyzing the "hemicellulose" and "cellulose". Waksman and Hutchings (15) have previously reported such a loss in the fractionation of the organic matter of podsol soils, and more especially in the B horizons of such soils. They attempted to make a correction for the amount of "lignin" dissolved by analyzing the acid filtrates for total carbon, subtracting the carbon equivalents of the amounts of "hemicellulose", "cellulose" and hydrolyzed "protein" found present in the hydrolyzates, and calculating the remainder of the carbon to "lignin". The assumption that all of the residual carbon is "lignin" carbon seems scarcely justifiable, and indeed Waksman has later pointed out (16) that polyuronide hemicellulose may give rise to non-reducing carbon compounds in acid hydrolysis. Precise experimental evidence with regard to the amount of lignin actually passing into solution after acid hydrolysis appears as yet to be lacking. However, by adopting the procedure of Waksman and Hutchings, the authors were able to show that the hydrochloric acid hydrolyzate from two of the soils (Nos. 9 and 10, the pastured and cultivated samples respectively from the McK farm) actually contained considerable carbon in excess of the amount calculated to be contributed by the reducing substances and hydrolyzed "protein" content of this solution. It was also found that if this excess carbon were calculated as lignin the apparent "lignin" contents of these samples were increased to 48.98 and 50.47% of the organic matter respectively, while the total recoveries of organic matter were thereby raised to 90.24 and 84.48% for these soils. The amounts of "lignin" and the percentage recoveries thus obtained are in reasonable agreement with similar values reported by Waksman and Hutchings for podsol soils.

In view of the possibility of loss of lignin through solubility in the acid extracting solutions and in the wash water, it appears that the lower

apparent lignin values for the cultivated and the pastured as compared with the forested soils may be due to greater solubility in acids rather than to an actual loss of "lignin" from the soil as a consequence of cultivation. This point merits further investigation. Possibly it might be justifiable to differentiate two types of "lignin" in such soils, for example, mobile and immobile "lignin". A more direct method for the determination of the lignin content of soils than is at present available is greatly to be desired.

TABLE 5.—"PROTEIN" CONTENT OF ACID HYDROLYZATES AND INSOLUBLE RESIDUES AS PERCENTAGE OF TOTAL ORGANIC MATTER ($C \times 1.724$)

Sample No.	Location	"Protein" in acid hydrolyzates	"Protein" in insoluble residues
Forested samples:			
1	H farm	18.63	5.56
3	G farm	16.31	5.00
5	S farm	13.00	4.75
Means		15.98	5.10
Average deviations		±1.99	±0.30
Cultivated samples:			
2	H farm	22.00	6.56
8	H farm	17.54	8.63
4	G farm	16.81	6.19
6	S farm	18.63	5.82
10	McK farm	14.19	7.44
Means		17.83	6.93
Average deviations		±1.98	±0.89
Pastured samples:			
7	H farm	17.56	6.44
7A	H farm	17.81	7.94
9	McK farm	13.69	8.31
Means		16.35	7.56
Average deviations		±1.78	±0.75

It has previously been noted that the percentage of "protein" in the organic matter was, in general, somewhat higher for the cultivated than for the forested soils. When this apparent increase in the total "protein" content was examined more closely by means of a study of the various nitrogenous fractions, it was found that the most consistent change in the amounts of these fractions in the soils of the two series occurred in the fraction resistant to hydrolysis by acids. The "protein" contents of the acid hydrolyzates and the insoluble residues, as percentages of the total organic matter ($C \times 1.724$) of the soils, are given in Table 5. The nitrogen in the hydrolyzates obtained by the action of hydrochloric and sulphuric acids, when multiplied by the factor 6.25, is termed "hydrolyzable protein".

The nitrogen in the insoluble residues obtained by the action of these acids has been calculated similarly and termed "non-hydrolyzable protein". The differences in the "hydrolyzable protein" contents of the soils of the three groups are clearly not significant. However, the variations in the "non-hydrolyzable protein" contents of the cultivated and the pastured soils (particularly the latter) from those of the forested soils may be significant. This apparent trend is in harmony with the view that soil micro-organisms transform plant proteins into more stable proteins as decomposition proceeds.

The distribution of the nitrogen in the various fractions in terms of percentage of the total nitrogen was found to be of considerable interest. This is shown in Table 6, in which the nitrogen recovered in each fraction is expressed as a percentage of the total nitrogen of the sample as determined by the Kjeldahl-Gunning-Arnold procedure applied directly to the whole soil.

In terms of the percentage of the total nitrogen present in these soils the differences in water-soluble and amide nitrogen shown among the various groups of soils examined are seen to be small and are probably not significant. Nor is there any significant difference in the proportion of the nitrogen which is found in the insoluble residue of the forested as

TABLE 6.—DISTRIBUTION OF THE NITROGEN OF THE ORGANIC MATTER FRACTIONS AS PERCENTAGE OF THE TOTAL NITROGEN IN THE SOIL

Sample No.	Location	Water-soluble nitrogen	Nitrogen in the HCl hydrolyzate		Nitrogen in the H_2SO_4 hydrolyzate	Nitrogen in the insoluble residue	Percentage recovery
			Non-amide	Amide			
Forested samples:							
1	H farm	4.12	29.5	7.22	36.4	20.5	97.72
3	G farm	5.95	36.3	8.50	34.0	24.0	108.74
5	S farm	6.21	32.5	8.60	33.9	27.5	108.72
Means		5.43	32.8	8.11	34.8	24.0	105.06
Average deviations		±0.87	±2.4	±0.59	±1.1	±2.3	±4.89
Cultivated samples:							
2	H farm	5.41	37.8	9.73	24.9	21.7	99.59
8	H farm	7.33	37.3	7.94	31.1	35.8	119.49
4	G farm	5.12	35.0	8.08	30.1	27.0	105.33
6	S farm	6.72	40.3	7.28	31.4	24.6	110.24
10	McK farm	6.94	40.4	7.19	19.1	35.1	108.72
Means		6.30	38.2	8.04	27.3	28.8	108.67
Average deviations		±0.83	±1.8	±0.69	±4.3	±5.3	±4.97
Pastured samples:							
7	H farm	6.26	41.2	7.95	27.5	28.2	111.14
7A	H farm	6.71	44.7	11.18	10.3	29.5	102.38
9	McK farm	7.24	44.5	9.05	11.9	39.9	112.55
Means		6.74	43.5	9.39	16.6	32.5	108.69
Average deviations		±0.34	±1.5	±1.19	±7.3	±4.9	±4.21

compared with the cultivated series. The differences revealed by a similar comparison of the forested and the pastured soil groups seem likely to be significant. The non-amide nitrogen in the hydrochloric acid hydrolyzate appears definitely to constitute a larger proportion of the total nitrogen in the pastured soils and possibly also in the cultivated soils than in the forested soils. This change appears to occur mainly at the expense of the nitrogen in the sulphuric acid hydrolyzate. In the pastured soils the decrease in the nitrogen compounds hydrolyzable by sulphuric acid appears to be accompanied by an increase in both the non-amide nitrogen of the hydrochloric acid hydrolyzate and the non-hydrolyzable nitrogen of the insoluble residue.

The mean ratio of amide to non-amide nitrogen in the hydrochloric acid hydrolyzate was found to be $1 : 4.57 \pm 0.57$, with a range from $1 : 3.78$ to $1 : 5.62$, and with but insignificant differences in the ratios for the three groups of soils studied. This is a considerably narrower ratio than that found by Shewan for the nitrogen extracted by 2% hydrochloric acid solution from the leaf litter of forest soils. In view of the fact that Davies (1) has found peat protein to yield 3 to 5 times as much amide nitrogen as do plant proteins, the high proportion of amide to non-amide nitrogen found in these Appalachian upland podsol soils is perhaps an indication of the peaty nature of the humus.

It will be noted from Table 5 that the percentage recovery of nitrogen was almost invariably appreciably greater than 100%. The consistency of the sign of this difference appears to indicate that it is not due to the experimental error of the nitrogen determination. A possible explanation is found in the contention of Dyck and McKibbin (3) that the Kjeldahl method fails to account for all of the nitrogen in the organic matter of the muck and raw humus soils of Quebec. Dyck and McKibbin used a much more drastic hydrolyzing agent (20% hydrochloric acid) than those employed by the authors, and the amount of nitrogen which they found by the Kjeldahl process after hydrolysis was sometimes more and sometimes less than that obtained prior to hydrolysis, the extremes being 94 and 108.2% respectively. It seems possible that during reaction with the less powerful hydrolyzing agents used by the writers, or because of the treatment with cold 80% (by volume) sulphuric acid, nitrogen in forms difficult to recover by the Kjeldahl method without such treatments may have been converted to more easily recoverable forms, thus accounting for the high apparent recoveries obtained.

SUMMARY

The amount and nature of the organic matter in the plow-depth layer of eleven soils of the Appalachian upland podsol type have been investigated. These soils were of three classes, forested, cultivated and pastured. The cultivated soils have been far from intensively tilled. The results obtained show that differences in either the total amount of organic matter or in its composition which may be attributed to the different systems of culture or to the vegetative cover are small in most instances. However, while the differences are in general small, and while the number of samples studied is too few to permit of broad generalizations, the following trends have been noted.

1. The cultivated and pastured soils appear, some 75 years or more after deforestation, to be somewhat lower in total organic matter than the forested soils. Further, "protein" resistant to hydrolysis apparently forms a slightly larger proportion of the organic matter in the soils of the first two groups. This observation agrees with the generally accepted opinion that cultivation reduces the carbon content of soils more rapidly than the nitrogen content. There does not appear to have been any significant change in the non-hydrolyzable "protein" as a percentage of the total nitrogen, except possibly in the pastured soils.

2. The non-amide nitrogen in the hydrochloric acid hydrolyzate appears definitely to constitute a larger percentage of the total nitrogen in the pastured than in the forested soils, while there is a strong indication that this may also be true for the cultivated as compared with the forested soils. This change appears to be associated with a decrease in the nitrogen in the sulphuric acid hydrolyzate. The ratio of amide to non-amide nitrogen in the hydrochloric acid hydrolyzate is relatively high.

3. There is an indication that the "hemicellulose" content of the forested soils is higher than that of the cultivated and the pastured soils, the latter being especially low in this fraction.

4. Lower values were obtained for the "lignin" content of the cultivated soils than for the forested soils, while the soils of the pastured series were still lower in their content of this component. These differences may be more apparent than real, and are possibly the result of an increased solubility of the "lignin" of cultivated and pastured soils in dilute acid solutions.

Certain problems of analytical technique were encountered. Prominent among these is the low percentage recovery of the organic matter, the sum of the fractions determined amounting on the average only to about 80% of the total organic matter as calculated from the carbon content in the usual manner. The principal cause of this deficiency may possibly be found, as Waksman and Hutchings have indicated, in the loss of "lignin" in the acid hydrolyzates. On the other hand, the recovery of nitrogen from the various fractions exceeded the total nitrogen as determined by the Kjeldahl method applied to the whole soil. It is suggested that nitrogen compounds resistant to direct kjeldahlization may, by hydrolysis with dilute acids in presence of the mineral portion of the soil, or by treatment with 80% sulphuric acid in the cold, be converted to forms more readily amenable to determination by the Kjeldahl process.

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WATER SUPPLIES IN RELATION TO SURFACE TAINT BUTTER[1]

J. B. LINNEBOE[2]

Department of Agriculture, Edmonton, Alberta

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The term "surface taint" is applied to butter having a peculiar, objectionable odour and taste suggesting putrefaction. It is essentially a Canadian expression for a certain butter defect, although the defect itself probably has a world-wide distribution. Recently Cullity and Griffin (1) reported on a butter defect, "rabbito", occasionally noticed in Australian butter and which these workers think may be the same as our surface taint. In Alberta the defect is most prevalent during the summer months, but even then its occurrence is relatively rare.

INCIDENCE OF SURFACE TAINT IN ALBERTA

Table 1 shows the amount of Alberta butter placed as surface taint by the Dairy Produce Graders during the past 14 years, expressed as percentage of total butter graded. The number of creameries that were involved in each of these years is also given:

TABLE 1.—SURFACE TAINT BUTTER IN ALBERTA

Year	Butter graded surface taint	No. of creameries involved	Year	Butter graded surface taint	No. of creameries involved
	%			%	
1926	0.59	22	1933	0.12	11
1927	0.61	28	1934	0.15	10
1928	0.65	23	1935	0.14	9
1929	0.33	29	1936	0.29	19
1930	0.42	20	1937	0.42	30
1931	0.42	18	1938	0.38	30
1932	0.16	12	1939	0.09	17

Since most of the butter that enters the trade passes through the grading system, these figures furnish a reliable index as to the extent of surface taint butter in Alberta. It will be seen that, during the past 14 years, butter graded as surface taint at no time accounted for more than a fraction of 1% of the total graded.

Several years ago, in the investigation of an outbreak of surface taint in an Alberta creamery, there was isolated from defective butter an organism which would reproduce the defect when inoculated into pasteurized cream at churning time and also when introduced into the water used for washing the butter granules following churning. The morphological and general cultural characteristics of this organism were similar to those of *Achromobacter*

[1] Contribution from the Dairy Branch, Alberta Department of Agriculture, Edmonton, Alberta.
[2] Bacteriologist.

putrefaciens, as reported by Derby and Hammer (2). Bacteriological tests at the creamery in question disclosed that the organism was present in large numbers in the water as it left the well and consequently became distributed to all parts of the creamery. In view of this finding, it was thought worth while to make a systematic survey for organisms of the *A. putrefaciens* type in all creamery waters received at the laboratory for analysis.

METHOD OF SAMPLING AND ANALYSIS

Most of the water samples were taken by the Dairy Inspector. Samples were packed in ice, and in most instances, arrived at the laboratory within 12 hours.

The waters were subjected to routine tests for *Esch. coli*, agar counts at 37° C. for 24 hours, and gelatin counts at 20° C. for 48 hours, according to *Standard Methods of Water Analysis* (3). In addition, the water was plated for moulds and yeasts, and litmus milk was inoculated at the rate of 1%, incubated at 10 to 15° C., and observed for changes in odour and appearance.

For the isolation of organisms of *A. putrefaciens* type, nutrient agar (Difco), pH 7.2 to 7.5 was employed. Before pouring the plates, a sterile solution of ferric ammonium citrate was introduced at the rate of 0.5 cc. of a 10% solution to each 10 cc. of agar. The plates were incubated for 7 days at 25° C. Any well isolated colony which during that time had made a depression in the medium, varying in extent from slightly sunken to one resembling gelatin liquefaction, was picked into litmus milk and incubated at 25° C. If the culture produced the characteristic surface taint odour and changed the appearance of the milk through the reduced stage, digestion to a final light amber colour, it was then taken as a possible *A. putrefaciens* culture, replated to insure purity and further identified. In determining the action on carbohydrates it was found rather difficult to obtain consistent results, because of the fact that the organisms generally were weak fermenters and liberated ammonia freely. The medium employed consisted of 1 part Ringer's solution to 4 parts of distilled water. To this was added 0.05% peptone (Difco) plus the carbohydrate (1%). Changes in reaction were followed potentiometrically by transferring aseptically 1 cc. lots of the culture at frequent intervals.

It may be pointed out that, while the numerous pure cultures secured in the course of this study in the main agreed with the description of *A. putrefaciens* as given by Derby and Hammer (2), there were certain aspects in which some of the cultures differed. It was thus observed that several of the cultures grew well at 37° C., and of the 4 carbohydrates employed in the routine fermentation tests, viz., dextrose, galactose, saccharose, and maltose, some cultures were found that fermented all these carbohydrates with the production of acid, but there were a few cultures that did not produce acid from any of these sugars. Although these differences in growth temperature and fermentation capacity have remained rather constant over a period of several years, in this discussion any culture with the general characteristics of *A. putrefaciens* and the capacity for producing surface taint in butter is considered as of the *A. putrefaciens* type.

RESULTS

Since 1935 some 200 creamery waters, representing 52 Alberta creameries and including practically all those that have been troubled with surface taint butter during that time, have been examined.

Of these 52 creameries, 9 were found to have organisms of the *A. putrefaciens* type present in the water as it left the well. The creamery mentioned in the introduction was one of them, and since it has been particularly well studied, may be taken as an example: the source of water supply was a drilled well, 237 feet deep, through clay and sandstone, the casing extending well above the ground and set in cement as a protection against surface drainage.

About the time the first outbreak of surface taint occurred at this plant, the well water was submitted to the Provincial Laboratory, Department of Health, for analysis, chemical and bacteriological, and given a favourable report. During the years in which the writer has been interested in this water supply, the bacteriological analysis of the water, sampled at the well head, has given the following results:

Esch. coli: Absent in 10 cc. lots.

Nutrient agar, 37° C., 24 hours: 50 to 100 organisms per cc.

Nutrient gelatin, 20° C., 48 hours: Total, 2,000 to 4,000 organisms per cc.

Gelatin liquefiers: 1,000 to 3,000 per cc. (approx.).

Moulds and yeasts: 0.

Litmus milk, 10° to 15° C.: Surface taint odour and reduction.

From a public health point of view, as expressed by the *Esch. coli* test and the agar count at 37° C., the water was satisfactory. In this particular case, however, the predominant organisms were ones which did not grow at all at 37° C. but grew rapidly at 20° C. Added to this, the fact that the majority of the low temperature organisms were of the *A. putrefaciens* type which give rise to surface taint indicates that the water was unsuitable for buttermaking purposes.

In instances like this, where the public health report was such as to give confidence regarding the purity of the water, it has often proven a rather difficult matter to convince the creamery operator that the water, nevertheless, was at fault when used for buttermaking purposes. Although a satisfactory public health report is a prime requisite of creamery waters, in itself it is no guarantee that the water is safe from a buttermaking point of view. When it is realized that butter in the creamery refrigerator, and afterwards, is often exposed to temperatures ranging from 5 to 15° C., organisms that can grow within these limits and produce undesirable changes in the butter become of particular significance and need to be taken into account when judging the bacteriological suitability of a water for buttermaking purposes.

EFFECT OF STORAGE

When surveying a creamery's water supply it has been the practice to collect two samples, one as the water leaves the well and the other as it enters the churn. Since most creameries are equipped with a holding tank to which the water is first pumped, this second sample, taken as the water enters the churn, usually represents stored water and, at times, water that had been passed through a filter.

In this study, it was found that, in addition to the 9 creameries where organisms of the *A. putrefaciens* type were present in the well water, 5 additional plants had the organism present in the water as it entered the churn, although the well water itself appeared to be free. It is a matter of everyday observation to have the sample at the churn yield counts that are far higher than those of the water at the well, because of contamination from the tank and growth during storage, and it will continue to be so until the holding tank is given the same daily attention regarding sanitation as is other creamery equipment coming in direct contact with pasteurized cream or butter.

While the higher counts obtained at the churn thus may be considered the result of storage, the contamination of the water after it leaves the well with organisms of the *A. putrefaciens* type, as observed at 5 creameries, has to be explained in some other way. As an illustration of how this condition may be brought about, the experience at one creamery may be cited, more particularly since it involved a condition that is found to exist at a number of plants.

The creamery in question was using a city water supply. In addition it had a reservoir located outside the plant and from which water for cooling purposes and for boiler uses was drawn. The purity of the city water, as sampled at the main, was never to be questioned, whereas the water from the reservoir was highly contaminated and contained large numbers of organisms of the *A. putrefaciens* type.

The significant point is, that at this creamery, part of the water line system was used intermittently for conveying city water and water from the reservoir. Consequently, there were times when water entering the storage tank was a mixture of the two. It may be added that this creamery had experienced considerable trouble from surface taint butter.

FARM WATERS

While the study of creamery waters was in progress an opportunity was afforded to examine certain farm waters. It was known that organisms of the *A. putrefaciens* type grow readily in cream of low acidity, and since in practice on the farm it would be difficult to entirely avoid contamination of milk or cream from the water supply, it was deemed of interest to know something of the distribution of the organism in farm waters.

In all, 55 farm waters were examined. From 6 of them, organisms of the *A. putrefaciens* type were isolated. Assuming that the organism is present in approximately 10% of farm waters, its occurrence in the raw cream received at the creamery is to be expected occasionally. This would be true at plants receiving mostly sweet cream and cream that has been held at a fairly low temperature on the farm.

DISCUSSION

Through the work on creamery waters combined with observations regarding the distribution of surface taint butter in Alberta, it has been noticed that some creameries having a few organisms of the *A. putrefaciens* type in their water supply have had no outbreak of surface taint for a period of a year or more, although, as far as it is known, the water has not been

treated in any way. Furthermore, at plants where the well water was heavily contaminated with *A. putrefaciens* and where it could be assumed that every churning of butter turned out contained the organism, this defect in the butter appeared rather spasmodically, often limited to one churning, or a few at the most out of a year's make, indicating that the mere presence of the organism does not necessarily mean that the defect will appear in the butter.

On the other hand, surface taint butter has made its appearance at creameries where organisms of the *A. putrefaciens* type could not be isolated from the water and where bacteriological surveys failed to show their entrance at any other point in the process of manufacture, suggesting that agents other than organisms of the *A. putrefaciens* type can cause surface taint butter.

Whenever an outbreak of surface taint occurs at a creamery it has long been routine procedure, as a preliminary step, to ascertain the creamery's mould and yeast record. If the mould and yeast counts of the butter were high, assistance was given the creamery in locating the cause.

Particularly during the years immediately following the introduction of the mould and yeast counts of butter by the Dairy Branch in 1925, it was a rather common experience to find that high mould and yeast counts of the butter were the result of contamination from raw cream, due to faulty pasteurization, failure to drain off the faucet cream, leaky valves, etc. It is significant that there are creameries on record where improved methods of pasteurization eliminated surface taint and where afterward, over a period of 10 years, no recurrence has been observed. Since the passing of raw cream into the system may mean the establishment of the surface taint cause at other points, for instance at the churn, it is apparent that in the control of surface taint, pasteurization of all the cream and the proper sanitation of all equipment with which the pasteurized cream and the butter comes into contact, must be effected. Pasteurization of cream, in conjunction with a pure water supply, appears to constitute the important precautions in the control of surface taint butter.

SUMMARY

1. During the last 14 years, surface taint butter in Alberta has constituted from 0.09% to 0.65% of the total butter graded.

2. Of 52 Alberta creamery water supplies examined, 9 were found to contain organisms of the *A. putrefaciens* type as the water left the well. An additional 5 creamery waters had the organism present in the water as it left the holding tank. Six out of 55 farm waters contained the organism.

3. The occasional passing of contaminated water through the regular water lines constitutes a possible source of contamination of a creamery's water supply with organisms of the *A. putrefaciens* type.

4. The ordinary public health bacteriological analysis does not necessarily indicate the suitability of a water for creamery purposes and may be entirely misleading.

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ADJUSTING APPLE YIELDS FOR DIFFERENCES IN SIZE OF TREE[1]

J. C. WILCOX[2]

Dominion Experimental Station, Summerland, B.C.

In field trials of the effects of different treatments on apple trees, the ultimate measure of effectiveness is the quantity and quality of crop produced. Among those factors affecting the quantity in marked degree is what we commonly term the "bearing area" of the tree. This in turn is dependent on the size and age of the tree and on various other factors. In the discussion below, the term "tree size" will be used to represent bearing area only, not tree weight or tree spread. If the crops produced by individual trees are to be compared directly, it is obvious either that trees of almost exactly the same size must be used, or that some means must be employed for adjusting the yields for differences in tree size. In field trials with fruit trees in the Okanagan Valley in British Columbia, it has been found very difficult, and in many cases impossible, to obtain sufficiently large blocks of trees that are all of the same or nearly the same size. Accordingly, an investigation has been conducted into possible methods of adjusting the yields for differences in tree size.

REVIEW OF LITERATURE

Much study has been devoted to the relationship between the trunk circumference and the weight of the top of the tree. In 1919, Tufts (12) reported very high positive correlations between the trunk circumference and the weight of the top with 2-year-old walnut, almond, and peach trees. He believed that these high correlations could not be expected with bearing trees. In 1921, Heinicke (5) obtained a curved line when he plotted the trunk circumferences against the weights of young apple trees. A 2× increase of the former was accompanied by a 7.3× increase of the latter. In 1928, Sudds and Anthony (10) found with apple branches a closer correlation between the cube of the circumference and branch weight than between circumference and branch weight. In 1930, Collison and Harlan (1) obtained a correlation of +0.972 between trunk circumference and weight of top. In 1931, Smith, Kinnison and Carns (8) reported very high correlations between the cross-sectional areas of the trunks and the top weights of grapefruit trees. In 1933, Knight and Hoblyn (7) obtained a high correlation between the cross-sectional areas of the trunks and the top weights of young apple trees. As the trees increased in size, however, the weight of scion per sq. cm. of cross-sectional area increased steadily. The cross-sectional area of the trunk was found to be less than the sum of those of the main branches. It was pointed out that the cross-sectional area of the trunk cannot be expected to be uniformly proportional to the total weight of the top of the tree when trees of different

[1] Contribution No. 567 from the Division of Horticulture, Experimental Farms Service, Dominion Department of Agriculture, Ottawa, Canada. Presented on June 20, 1940, at the meetings of the Western Section of the American Society for Horticultural Science at Seattle, Washington, U.S.A.

[2] Assistant Superintendent (fruit tree nutrition and irrigation investigations).

size are used. In 1937, it was pointed out by the writer (14) that the use of the cross-sectional area of the trunk as a measure of tree size is affected by severity of pruning, tree crowding, and certain other factors.

A fewer number of workers have reported studies of the relationship between the size of the trunk and tree yield. In 1919, Hedrick and Anthony (4) obtained a straight-line trend between the cross-sectional areas and the yields of apple trees. In 1920, Waring (13) obtained a high correlation between trunk circumference and yield of apple trees. Sudds and Anthony (10) reported a lower correlation of yield with trunk circumference than with the square or the cube of the circumference. In 1931, Hoblyn (6) reported finding a closer relationship between cross-sectional area of trunk and yield than between trunk circumference and yield.

Attempts by investigators actually to adjust the yields of fruit trees for differences in tree size appear to have been infrequent. In 1932, Degman, Furr, and Magness (2) calculated the number of apple fruits per 100 sq. cm. of cross-sectional area of the trunk. The same year, Fletcher (3) recorded apple yields in terms of the number of bushels per 100 sq. cm. of cross-sectional area of the trunk. Essentially the same method was used by Tingley and Potter (11) in 1934.

SOURCE OF DATA

There have been two major sources of material for the studies undertaken in the Okanagan Valley: first, some 400 bearing McIntosh trees in grower-owned orchards at different points in the Valley; and second, Delicious and Jonathan trees in the check plots at the Dominion Experimental Sub-station at Kelowna. Since the McIntosh data are much the more extensive, it is proposed to report here only the findings based on these data. The findings from the Delicious and Jonathan trees, however, appear to conform fully with those from the McIntosh.

The McIntosh trees have all been of bearing age, but have varied considerably in size. They have been spaced at different distances apart in the different orchards; the most popular spacing, however, being 30 × 30 feet apart on the square. For the most part, they have been situated in solid blocks of McIntosh trees, such that each tree has been surrounded on all sides by other McIntosh trees of approximately the same size. In 1937, a small block of 4 or 5 trees was tagged in each of the orchards used for the studies. Records have been obtained on these trees now for three years. Among the records have been yield and trunk circumference, obtained as follows:

Yield

All the orchards have been visited just prior to the picking season, and the selected trees tagged with mimeographed cards on which were spaces for marking down the yield at each picking. The growers have for the most part co-operated exceptionally well in recording the required data at picking time. After harvest, the yields have been copied from the tags, and at the same time an estimate has been made of the drops that have been left on the ground. Adding the two together has given the total yield. It has been measured in terms of loose, level-filled bushel boxes, to the nearest half box.

Trunk Circumference

This has been measured at the same place on the trunk each year, late in the fall, and to the nearest millimeter. In view of the fact that the majority of the trees have been headed rather low, the positions chosen for measurement have been for the most part approximately midway between the crown and the lowest limb. Care has been taken to avoid protrusions or other irregularities. Each position has been marked permanently with a nail on either side of the trunk. The loose bark has been scraped off each time before the measurement has been made.

The majority of the trees have been more or less subject to biennial bearing. Accordingly, the yields have been averaged for 1937 and 1938, and again for 1938 and 1939, before any attempt has been made to adjust them for differences in tree size. This procedure has eliminated in large measure (though not entirely) the effects of biennial bearing on yield. The trunk circumference measurement chosen for direct comparison with a 2-year yield average has been that taken the fall of the first of the two years, this being midway between the two growing seasons.

TESTS OF METHODS OF MAKING YIELD ADJUSTMENTS

The only measurements tested for use in adjusting the yield for differences in tree size have been the trunk circumference, the cross-sectional area of the trunk, and the geometric mean of these two. The four different approaches noted immediately below were all tested out by the use of data based on the average yields for 1937–38 and 1938–39, from 75 trees 30 × 30 feet apart on the square, each of which was surrounded by McIntosh trees of approximately the same size. These 75 trees were located in 19 orchards, mostly in the Kelowna district.

(1) Trunk Circumference

It was assumed that the trunk circumference would only be satisfactory for direct use in adjusting yields if it were to vary in the same proportion as the yield. It was assumed further that if this were so, then the adjusting of the yield in accordance with the trunk circumference should automatically eliminate any correlation between these two measurements. To determine this, all yields were calculated per 100 cm. of trunk circumference, by the use of the following formula:

$$\text{Yield per 100 cm.} = \frac{100 \times \text{actual yield}}{\text{trunk circumference}}\,.$$

The yields thus adjusted were then charted against the trunk circumferences. Both the 1937–38 data and the 1938–39 data showed definite increases in the adjusted yields with an increase in the size of tree. The 1938–39 data gave a coefficient of correlation of +0.259. This coefficient can be considered statistically significant, with odds of between 19 : 1 and 99 : 1. The coefficient was not calculated for 1937–38, but the chart distribution was very similar to that of 1938–39. It was obvious from this result that the yield adjustments were not great enough by this method to make up for the differences in size of tree. In other words, the trunk circumference increased less rapidly than did the bearing area of the tree, as represented by the yield.

(2) Cross-sectional Area of Trunk

As stated previously the cross-sectional area of the trunk has been used by other investigators as a means of adjusting yields. It was calculated from the trunk circumference by the use of the following formula:

$$\text{Cross-sectional area} = \frac{(\text{circumference})^2}{4\pi}.$$

The yields were then adjusted to a cross-sectional area of 1000 sq. cm. Both in 1937–38 and in 1938–39, the distribution charts showed a definite decrease in the adjusted yields with an increase in the size of tree, an effect just the opposite to that obtained with the trunk circumference. The coefficient of correlation between the adjusted yields of 1938–39 and the cross-sectional areas was -0.225, which can be considered statistically significant. By this method, then, the yield adjustments were too great. In other words, the cross-sectional area of the trunk increased more rapidly than did the bearing area, as represented by the yield.

(3) Geometric Mean of Circumference and Cross-sectional Area

Since the use of the trunk circumference did not give sufficient adjustment for size of tree, while the use of the cross-sectional area gave too much adjustment, it seemed reasonable to suppose that some measurement lying between these two should prove satisfactory. Two such measurements suggested themselves, the arithmetic mean and the geometric mean. Preliminary charts indicated that the geometric mean was the more satisfactory for use with the data at hand; accordingly, it was the only one investigated further. This measurement was calculated for each tree by the use of the formula: Geometric mean $= \sqrt{\frac{(\text{circumference})^3}{4\pi}}$. The yields were then adjusted to a geometric mean of 300. Both in 1937–38 and in 1938–39, the distribution charts gave no visual evidence of any tendency for the adjusted yields either to increase or to decrease as the trees increased in size. The coefficient of correlation between the adjusted yields and the geometric mean in 1938–39 was $+0.013$. This coefficient is too low to be considered significant. By this method, then, the yield adjustments were neither too large nor too small. In other words, the geometric mean between the trunk circumference and the cross-sectional area of the trunk increased at practically the same rate as did the bearing area, as represented by the yield. It would appear that in this particular case the adjustment of yields on the basis of the geometric mean was quite satisfactory.

As noted above, the cross-sectional area and the geometric mean were calculated directly from the trunk circumference. This was because the trunk circumference was the measurement actually recorded in the field. It should be pointed out, however, that the fundamental variable concerned in trunk size is the radius (14). Had the trunk diameter been measured instead of the circumference, it could just as readily have been used as the basis for the further calculations.

(4) Regression Coefficient

The procedure followed in each of the above three cases, i.e., the adjusting of individual yields in direct proportion to the trunk measurement

followed by correlation of this measurement with the adjusted yields, constituted a test of linearity between the trunk measurement and the unadjusted yields. In other words, the geometric mean was the only one of the three that gave straight-line trends when plotted against unadjusted yields. The lines of trend tended to curve downward with the use of the trunk circumference, and upward with the use of the cross-sectional area of the trunk. In so far as linearity alone is concerned, a much simpler procedure could have been used, based on the fact that linearity is the result of constant proportionality between the two measurements being correlated. As noted below, trees that were starting to crowd badly did not, in this investigation, exhibit linearity between geometric mean and yield, and so could not safely have their yields adjusted on an assumption of linearity.

Although the geometric mean has in most cases shown good linearity with yield, there has occasionally been some deviation from it. This variation can be expected with any measurement that may be found suitable for any particular district or variety. Where such deviation has occurred, the safest plan has been found to be to make adjustments on the basis of the regression coefficient, rather than on the basis of direct proportionality as was done above. Indeed, this method appears to be preferable for general use, whether deviations from linearity are apparent or not. The trunk measurement used in calculating the regression coefficient should naturally be that showing the closest linearity with yield; in this case, the geometric mean.

In making adjustments by the use of the regression coefficient, the first step is to calculate the regression equation. The formula used is

$$y = \bar{y} + \frac{Sd_x d_y}{Sd_x^2}(x - \bar{x}),$$

in which

y = value of y (yield) as determined from the x value (size of tree),
$\bar{y}$ = mean of the y distribution,
$\bar{x}$ = mean of the x distribution,
$Sd_x d_y$ = sum of the products of the individual deviations of the two distributions,
Sd_x^2 = sum of the deviations squared of the x distribution (9).

The coefficient of x in this equation is known as the regression coefficient. In making actual use of the equation, it is assumed that y represents yield, and x represents a suitable measurement of size of tree. Where there are other factors affecting yield that are closely correlated with the size of tree, it is necessary to calculate the regression equation in such a way as to eliminate the effects of these other factors. The formula used is somewhat more complicated than that given above (Snedecor (9), Chapter 13). In certain tests by the writer, the vigour of the tree has been found to be correlated directly with yield and inversely with size of tree; that is, the larger the trees, the less the vigour. In this case, it has been necessary to eliminate the effect of vigour in calculating the regression coefficient.

The equation representing the regression of yield on the geometric mean of the trunk circumference and the cross-sectional area of the trunk in 1938–39 was:

Average yield per year = 0.0667 × geometric mean + 5.90.

This meant that a change of 0.0667 in geometric mean was accompanied

by a change of 1.0 box in yield. The second step was to decide on a standard size to which all trees would be adjusted. The size chosen was a geometric mean of 300. The adjusted yields were then calculated by the use of the following equation:

$$\text{Yield per G.M. of } 300 = \text{Actual yield} + \text{regression coefficient} \times (300\text{-actual geometric mean}).$$

Some examples of actual adjustments are given in Table 1. The adjusted yields were correlated back to the geometric means, and as would be expected the coefficient of correlation was practically zero.

TABLE 1.—METHOD OF MAKING YIELD ADJUSTMENTS BY USE OF REGRESSION COEFFICIENT
(With regression coefficient = 0.0667.)

Yield	G.M.*	300 minus G.M.	Deviation × 0.0667	Adjusted yield
17.0	152	+148	+9.9	26.9
18.6	264	+ 36	+2.4	21.0
22.3	302	− 2	−0.1	22.2
30.1	378	− 78	−5.2	24.9
34.2	404	−104	−6.9	27.3

*G.M. = geometric mean of trunk circumference and cross-sectional area of trunk.

It will be noted in Table 1 that after adjustment for differences in tree size, there is still a good deal of variation among the yields. This can always be expected. The fact is that size of tree is only one of the many factors affecting yield, and adjusting for only one factor cannot possibly eliminate all variability. What it does is to eliminate any relationship between the variation in this particular factor and the variation in yield. At the same time, the total variability in yield may be considerably lessened.

The regression method of adjustment can be applied not only to individual tree yields, but also to average or total plot yields. The significance of the differences between plots can then be determined by the usual analysis of variance, the whole procedure constituting an analysis of covariance (9, Chapter 12). This method has been used by the writer for studying differences in yield as affected by district, season, soil type, treatment, etc. It should be noted again that a prerequisite for the use of the regression method is that the two sets of data shall exhibit linearity. Although in this investigation the geometric mean of the trunk circumference and the cross-sectional area of the trunk has been found to satisfy this requirement when used for adjusting yields, it is not improbable that in other districts or with other varieties some other measurement of tree size may be found preferable.

SOME ORCHARD CONDITIONS INFLUENCING RELIABILITY OF YIELD ADJUSTMENTS

There are no doubt a large number of orchard conditions that affect the reliability of any method that may be used for making adjustments of yield for differences in tree size. Among those studied in this investigation have been severity of pruning, tree crowding, empty spaces, and distance of planting. The findings presented below are based on data from most of the 400 McIntosh trees previously mentioned.

Severity of Pruning

The more severe the pruning, the less rapid has the increase in the "bearing area" of the tree been found to be, in comparison with the growth of the trunk (14). This effect does not appear to have been of any serious consequence, however, until the trees have been subjected to different pruning treatments for several years. Of two trees that have had trunks of equal size and have been of equal vigour, that tree has tended to bear the greater crops that has for some years prior to recording been pruned the less severely. In many of the field plot tests that have come under the observation of the writer, the differences in severity of pruning do not appear to be sufficiently great to invalidate the use of yield adjustments. In long-time pruning experiments, however, or in the use of trees from different orchards that have been receiving widely varying types of pruning, any method of using the size of the trunk for making yield adjustments should be employed with caution.

Tree Crowding

Between the time when trees have come into normal bearing and the time when they have started to crowd badly, their yields have been found to increase fairly uniformly with an increase in size of trunk. In other words, within this range of size the distribution charts of yield plotted against geometric mean of trunk circumference and cross-sectional area of trunk have given practically straight-line trends. Once the trees have started to crowd badly, however, a further increase in the size of the trunk has been accompanied by a lessening increase and in some cases even a levelling-off of the yield. At this point, therefore, the line of trend on the chart has become curved. The primary reason appears to be that owing to shading or to increased severity of pruning, the effective bearing area of the tree has tended to come to a maximum when crowding of the tops has come into play. It is obvious that after this stage has been reached the use of the size of the trunk to adjust yields is out of the question.

Empty Spaces

A tree in an orchard is normally surrounded by 4 trees (square planting) or by 6 trees (hexagonal planting), all equidistant from it. It has been found that where one or more of these surrounding trees have been missing, the yield of the tree under consideration has tended to be greater than where it has been surrounded by a complete complement of mature trees. As a general rule, an empty space or two has induced an increase not only in the tree yield but also in the trunk circumference. However, increase in the size of trunk has not been sufficiently great to correct for the increase in yield, when adjustment has been made by either the geometric mean method or the regression coefficient method. The deviations in yield have been so great in some cases that erroneous results have been obtained when trees with one or two adjacent empty spaces have been compared with trees having no adjacent empty spaces. Moreover, where the neighbouring trees have been much smaller than the tree under observation, much larger, or of a variety with a different type of growth, the results have also been questionable. The analysis of covariance procedure has been tried in an attempt to adjust for blank spaces, but without much

success. The only logical way to overcome the difficulty appears to be to confine the choice of trees to those that are surrounded by a full complement of trees of the same variety and of approximately the same size.

Distance of Planting

The trees used as a basis for these studies varied in their distance of planting from 25 $\times$ 25 feet on the hexagonal to 35 $\times$ 35 feet on the square, the number of trees per acre thus varying from 80.4 to 35.6. As would be expected, the more closely planted trees have given a lower average yield per tree than have those planted farther apart; moreover, they have averaged less even when trees with the same size of trunk have been compared. As a result, it has been found impossible to make direct comparisons between plots of trees planted at different distances apart, even when adjustments have been made for differences in size of trunk.

A procedure that has shown promise in adjusting for different distances of planting in correlation work has been as follows: *(a)* Multiply the yield per tree by the number of trees per acre, to obtain the rate of yield per acre. *(b)* Determine the geometric mean of the trunk circumference and the cross-sectional area of the trunk. These measurements are made in centimetres. *(c)* Divide the geometric mean by the area of ground occupied by the tree, in square feet. The ratio thus obtained is termed the "trunk-ground" ratio. It represents the bearing potentialities of the tree per unit area of ground occupied. The McIntosh trees used in these studies have had trunk-ground ratios ranging from about 0.17 to 0.48. *(d)* Adjust the yield (per acre) for differences in tree size by the use of the regression coefficient obtained by the regression of yield on the trunk-ground ratio.

To test the use of this procedure, the equation for the regression of yield per acre on trunk-ground ratio was determined for 142 McIntosh trees in 1938–39. It was found to be

$$\text{Yield} = 2450 \times \text{trunk-ground ratio} + 415.$$

The trees were then divided into three groups in accordance with their distance of planting: *(a)* less then 900 square feet per tree, *(b)* 900 square feet, and *(c)* more than 900 square feet. The mean yields and mean ratios were determined for the three groups. By the use of the analysis of covariance (9, Chapter 12), the mean yields were adjusted for mean deviations in the trunk-ground ratios. The yields per acre thus adjusted were 1147, 1219, and 1194, in the three respective groups. There was no trend evidenced by these yields, nor any statistically significant differences among them. From this it was concluded that the procedure shows promise as a means of adjusting yields for differences in distance of planting.

APPLICATION TO INVESTIGATIONAL METHOD

The problem of making adjustments for tree size has been encountered in two types of investigational work at the Dominion Experimental Station at Summerland: first, field plot work; and second, correlation work. As already intimated, it has been found difficult to obtain large enough blocks of trees of uniform size to make satisfactory comparisons between plots without making some adjustments for size differences. The usual method of doing this has been to use the analysis of covariance procedure, i.e., to

correlate yield with tree size, using all the trees in the test; to adjust the mean of each treatment in accordance with the regression coefficient; and to determine the significance of the differences between the means by the analysis of covariance.

In certain fertilizer experiments that have come under the writer's observation, the trees were apparently of approximately the same size in the respective plots when differential treatments were first initiated. However, the subsequent growth was very much less in those plots receiving no nitrogen than in the other plots, so that after a few years the no-nitrogen trees are now much smaller than the others. Two approaches are being used to determine the effect of treatment on yield: (1) To determine the long time effect of an unchanging fertilizer practice, comparisons are being made with no adjustments for tree size. In other words, a smaller tree is, from this viewpoint, accepted as a part of the general effect. (2) To determine the current effects of a deficiency of nitrogen, it is necessary to make some adjustment for differences in tree size. This is done by the analysis of covariance method, as noted above. In such a case, it is necessary to eliminate from the regression equation of yield on tree size the effects of differences in vigour.

In the newer field plot experiments with fruit trees that have been laid out at this Station, the practice has been adopted of taking yield, growth, and other records for a period of at least two years (and preferably four) before differential treatment is initiated. The records after the start of differential treatment are then divided by the records before that time, the ratios thus obtained being used in making the plot comparisons. In this way, the difficulty of differences in tree size is obviated to some extent. However, the trees in all plots may not increase in size at the same rate (as noted above), so that as a rule it is still considered advisable to adjust for size of tree before making the final comparisons.

Studies are now being made of the effects of a number of factors on apple tree growth and yield, such as biennial bearing, soil type and depth, and soil analysis. One method that is being used is to correlate these factors with yield and with one another. As possible sources of material for these correlations, records are being obtained from a large number of trees of the same variety but of different size and different distance of planting. The question arises as to whether it is safe to make correlations under such conditions. Thus far, satisfactory results have been obtained by following the procedure noted under "Distance of Planting" above.

It appears to the writer that one of the greatest possible sources of error in interpreting the effects of field plot treatments on fruit trees may be differences in size of tree. It would seem advisable at least to ascertain to what extent the trees do vary in size, and to what extent this variation is accompanied by a variation in yield; then, if necessary, to make yield adjustments for such differences in tree size as are found to exist. The use of the regression method is suggested as being the most reliable of those tried in this investigation.

SUMMARY

Studies were made of several possible methods of adjusting apple yields for differences in size of tree. The source of material for the studies was some 400 McIntosh trees in grower-owned orchards. The adjustment

was too small when made to a constant trunk circumference, too large when made to a constant cross-sectional area of the trunk, and about right when made to a constant geometric mean of the circumference and the cross-sectional area. The most reliable method, however, appeared to be the use of the regression coefficient obtained from the regression of yield on size of trunk.

Large differences in severity of pruning were found to lessen the reliability of the methods used for making the yield adjustments. The adjustments were found to be quite unreliable after the trees had started to crowd badly. The same was true where there were empty spaces or small trees adjoining the mature trees on which the records were being taken. It was found that with mature trees, satisfactory results could be obtained only where each tree was surrounded by a full complement of other trees of the same variety and size. Trees planted at different distances apart could not be compared with one another except by adjusting for both size of tree and distance of planting. A method is suggested for expressing the size of tree per unit area of ground occupied.

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BOOK REVIEW

MORTENSON, W. P. "Milk Distribution as a Public Utility". The University of Chicago Press, 5750 Ellis Avenue, Chicago ($2.50).

In so far as it is possible to make an analysis of a publically controlled industry on an abstract basis, the author has done an excellent piece of work. The book summarizes many factual data on milk distribution in the United States and the costs involved in this industry and is a valuable contribution to the perplexing problem of how these costs can be reduced. It raises all the major points which would be involved in placing milk distribution in the category of a public utility. In analysing each point the author brings into the discussion studies carried on by universities and colleges and by state and federal agencies; relevant passages from congressional documents, court decisions, and many research publications are quoted.

A vast amount of time and an analytical mind were necessary to obtain and sort the facts on which the various chapters of the book are based. In conclusion the author states that the agitation for public control of milk distribution will come mainly from consumers and the greater the pressure upon consumer budgets the more rapidly can changes be expected in that direction. "From the standpoint of a disinterested observer the case for milk distribution under a unified system is very strong, and likewise, from that of the consumer the case for such a system is clear-cut. On the other hand, from the standpoint of the distributor and of organized labour the opposition will be powerful, while the producers, especially the organized producers, will not favour the change although they may be converted."

At the beginning of the volume the author develops a history of public control of milk prices in the United States. After the world-wide depression which began in the early 30's farmers demanded that the government "do something" about the low price of milk. The pressure for price regulation came mainly from producers but also to some extent from milk distributors. Many small dealer- and producer-distributors began marketing milk and in order to obtain a share of the market, they sold milk below the price formerly prevailing in the city. Distributors who were already established in the market met the price cut by passing all or part of the return back to the producer.

At least fifteen cities passed legislation establishing state control boards to regulate distribution. The author believes that state control boards exercised a real influence in stabilizing sadly disrupted markets, but that many of the major issues of the industry have scarcely been touched, to say nothing of having been solved, by control boards. Little attention has been given by control boards to studies concerning marketing efficiency, methods of reducing costs and ways of narrowing margins in milk distribution.

If regulation is to continue, increased attention will be centred on the fundamental problem of narrowing the margin between producer and consumer prices.

The division of milk distributors' sales dollar into various cost items is presented as well as the source of the information used in the calculations. Each cost item is analyzed in some detail and the extent to which savings might be made by a unified system of milk distribution is discussed in considerable detail, item by item. It is pointed out that if the costs of processing and distributing fluid milk are to be reduced materially the major reduction must come from the large cost item, namely, total labour, and to a lesser extent from the next cost item which is depreciation. Generally speaking, the larger the company the greater the opportunity for efficiency in the use of labour and this is especially true on the milk delivery routes. On the other hand, the high wage rates which are usually paid by larger companies, mainly because their employees are generally more effectively organized, tends to counteract the efficiency which results from handling a large volume of milk.

Expenses of delivery directly to the family retail trade, accounts for roughly two-thirds of the total cost of retail market distribution.

On a basis of total operating costs of 5 cents per quart all labour amounts to a cost of about 2 cents per quart. Plant labour represents approximately 18 per cent of all labour. If it were possible, by a unified system of distribution under public utility control, to save 15 per cent on plant labour the probable saving per quart would be about 0.054 of a cent. If it were possible to save 25 per cent on plant labour costs the saving per quart would be about 0.125 of a cent.

In the main, the unit cost of milk delivery is determined by the size of the load carried and by the wage rate of the deliveryman. Data obtained from some 80 milk distributors in Wisconsin cities showed that collecting accounts and soliciting new customers required more than two-fifths as much time by deliverymen as was absorbed by the actual delivery, or one-third of the deliverymen's working time. New York State studies gave results which were very similar. Under a unified plan of milk distribution deliverymen would not be called upon to use their time to collect accounts or solicit new customers.

Interesting observations are presented from actual studies on the practice of permitting wagons of several different companies to deliver milk in the same city block. Delivery labour constitutes from 65 to 75 per cent of the total labour cost in most markets. The author summarizes, —"Judging from the results of other studies, which suggest possible economies ranging from 54 to 60 per cent in delivery through a unified milk distribution system, it would seem that an estimated saving of 38 to 46 per cent assumed in our calculations, are extremely conservative."

Expense for office labour would not be reduced by a unified system of milk distribution.

If it were possible under a unified system to cut salaries one-half, the saving per quart handled would be 0.25 to 0.35 of a cent.

Possible savings in depreciation of buildings, machines and delivery equipment are explored and the author arrives at the conclusion that by unification a saving of 0.14 to 0.18 of a cent per quart might be expected. Small savings might also be expected in repairs, advertising, bad debts, insurance, gasoline and oil, and by the elimination of profits. A table is

presented which shows that taking the estimated savings on all services into account, on the basis of a 5-cent distribution cost per quart, the unification of milk distribution under a public utility system should result in a saving of 1.92 cents per quart. On the basis of a 6-cent distribution cost, the saving would be 2.29 cents per quart. Considering United States markets with populations from 10,000 to 100,000 it is pointed out that savings of 1.5 to 2 cents per quart might be closer to expectation.

One chapter is devoted to a discussion of the points which must be considered respecting the acceptance by consumers of an adequate standardized service with lower prices as compared with a superior service at higher prices. The profits which large and small companies have been able to obtain in various markets over a period of years are discussed.

Those interested in the legal aspects of milk control in the United States will find the chapter which reviews court decisions involving the regulation of fluid milk illuminating. In his summary of this chapter the author states, "There would seem to be sufficient legal precedence for the position that the legislatures have power either to grant an exclusive franchise to a private corporation for processing and distributing milk or to delegate to the city or municipality the power to perform the function through municipal ownership.

Public ownership of the milk distributing system is contrasted with public control of privately owned milk distributing plants. The author explores the many difficulties which will be encountered in making milk a public utility. He believes the objections will be largely from those individuals and groups who are concerned with safe-guarding their own interests at the cost of social welfare as a whole. The shortcomings of public utility regulation from political, administrative, financial and labour viewpoints, are outlined and discussed. The short-run and long-run economic effects on producers and consumers of unified milk distribution under a public utility are considered and the author makes the following summary, "The key question with regard to both producer and consumer benefits depends largely upon whether the unified system would be operated with the high efficiency which such a set-up makes possible."

The book is written in clear and readable English and is well indexed.

—W. C. Hopper.